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THE AMERICAN JOURNAL OF SCIENCE.

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FOURTH SERIES.

VOL. IX—[WHOLE NUMBER, CLIX.]

No. 50.—FEBRUARY, 1900.

WITH PLATE I.

NEW HAVEN, CONNECTICUT.

1900.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 125 TEMPLE STREET.

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Cobalt,	.52	"
Phosphorus,	.20	"
Sulphur,	.06	"
	100.04	

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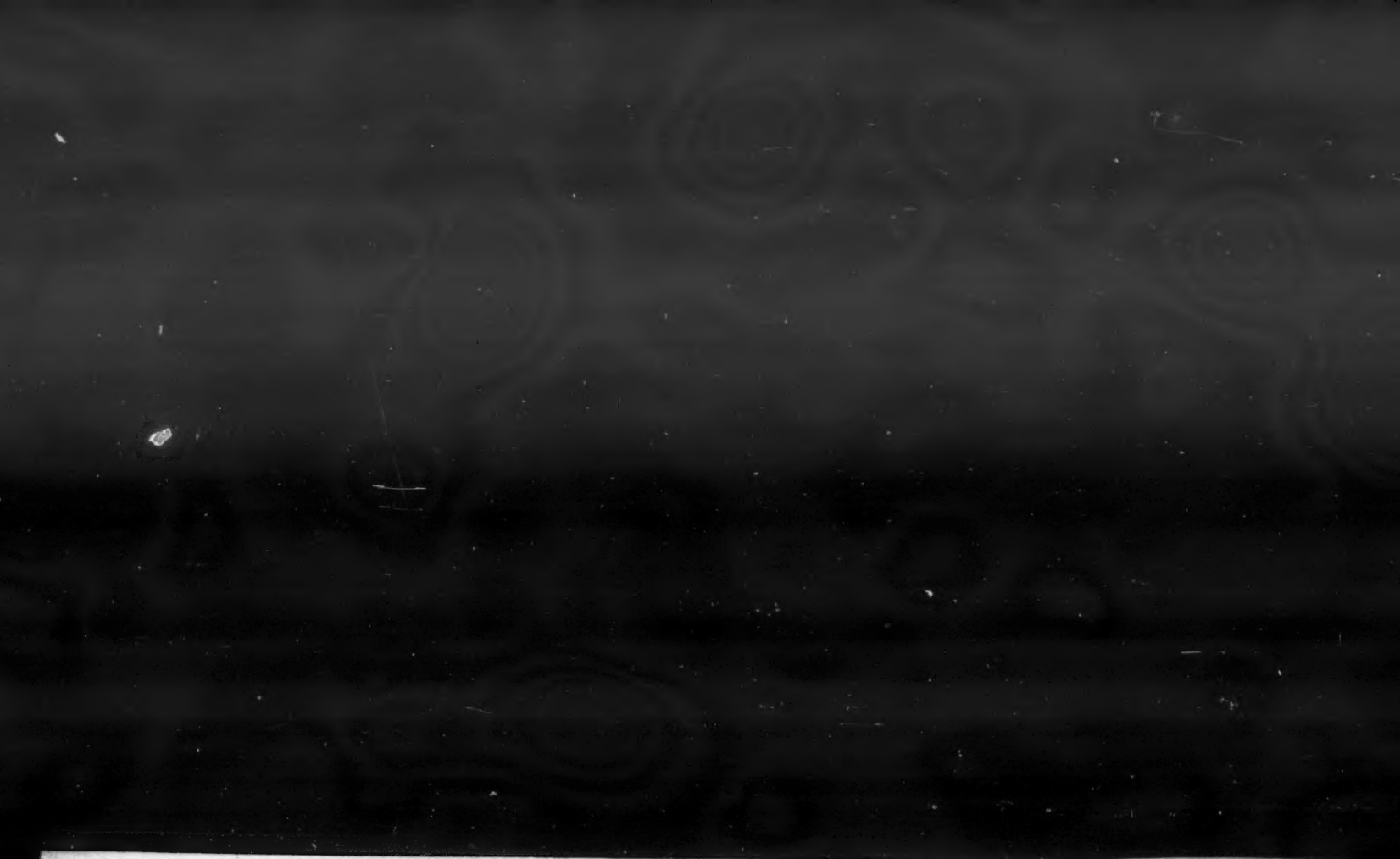

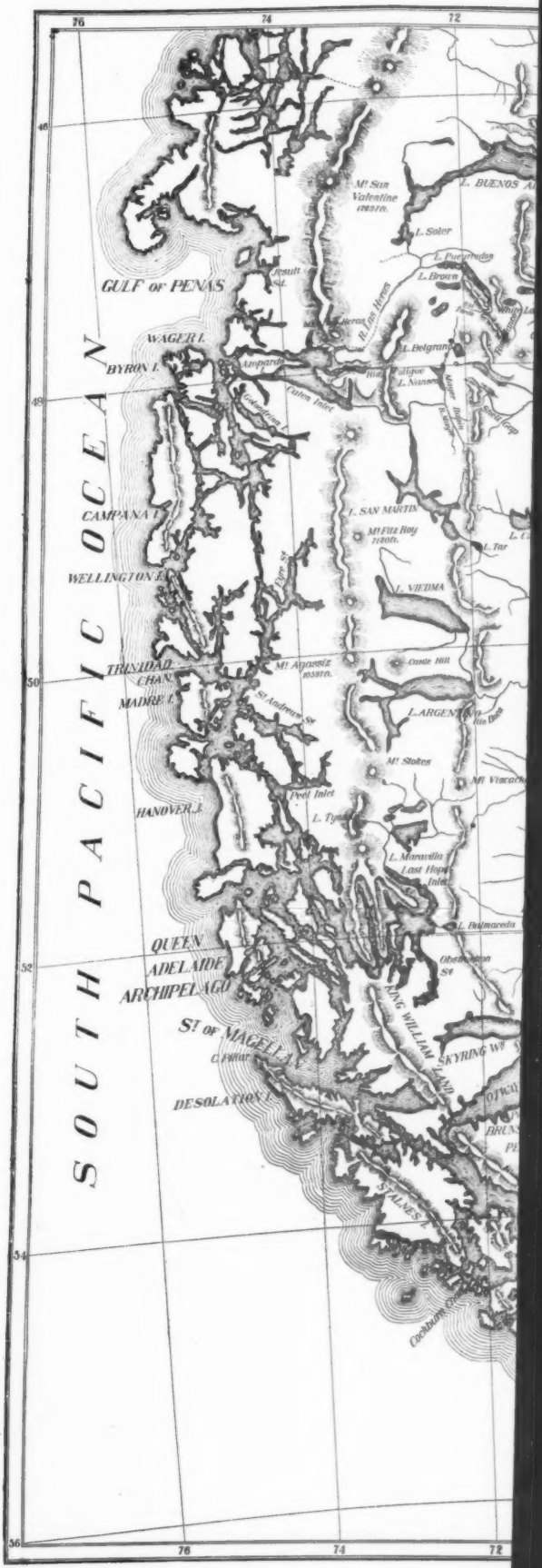
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SOUTH PACIFIC OCEAN
GULF OF PENAS
WAGER I.
BYRON I.
CAMPANA I.
WELLINGTON I.
TRINIDAD CHAN.
MADRE I.
HANOVER I.
QUEEN ADELAIDE ARCHIPELAGO
DESOLATION I.
Mt San Valentine 13,870 ft.
L. Solar
L. Pueyrredon
L. Brown
L. Belgrano
L. Nansen
L. SAN MARTIN
Mt Fitz Roy 11,000 ft.
L. VIEDMA
Mt Stokes
L. Buenos Aires
Obelisco Pass
Skyring Water
Strait of Magellan
Cape Froward
Stalnes I.
Cockburn Channel

MAP OF
SOUTHERN PATAGONIA
FROM A MAP OF
SOUTHERN ARGENTINA
BY DR. FRANCISCO P. MORENO.
with additions and corrections by
J. B. HATCHER
Scale of Miles
GULF OF ST GEORGE
SOUTH
ATLANTIC
OCEAN
SOUTH PACIFIC OCEAN
GULF OF PENAS
PORT DESIRE
PORT S. JULIAN
PORT STA CRUZ
PORT GALLEGOS
R. DESIRE
R. CHICO
R. SANTA CRUZ
R. SHEHUEN
R. Gallegos
L. BUENOS AIRES
L. SAN MARTIN
L. VIEDMA
L. ARGENTINO
L. Pueyrredon
L. Brown
L. Belgrano
L. Cardiel
L. Fagnano
L. Blanca
WAGER I.
BYRON I.
CAMPANA I.
WELLINGTON I.
TRINIDAD CHAN.
MADRE I.
HANOVER I.
QUEEN ADELAIDE ARCHIPELAGO
ST OF MAGELLAN
DESOLATION I.
KING WILLIAM ISLAND
BRUNSWICK PENINA.
TIERRA DEL FUEGO
SAN SEBASTIAN BAY
NAVARIN I.
HOSTE I.
STATEN I.
CAPE HORN
Mt Darwin
Mt Aymond
Mt Sarmiento
Mt Stokes
Mt Viscachas
Mt Fitz Roy
Mt Agassiz
Mt San Valentine
Punta Arenas
Beagle Chan.
Three Brothers
Jesuit Mt.
Sierra Ovejo
Sierra Ventana
Crystal Lake
Swan Lake
Spring Creek
Dry Creek
Fuca Inlet
Peel Inlet
Last Hope Inlet
Obelisk Pt
Skyring Water
Otway Water
Gallegos
Coy Inlet
Darwin Station
Direction Hill
Cape Virgin
Le Maire St.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VIII.—*Sedimentary Rocks of Southern Patagonia;* by J. B. HATCHER. With Plate I.

SINCE publishing my last paper on the geology of southern Patagonia,* I have spent two years in that region making a further study of its geology and bringing together important additions to our collections of fossil vertebrates and invertebrates. The results of these two additional years of field work, together with the more advanced stage now attained in the study of our collections of fossils, have greatly augmented the observations made during my first expedition and materially modified several of the opinions expressed in my former paper regarding the age and relations of the various sedimentary deposits of Patagonia.

Chief among the additional observations and resultant modifications of the former views as expressed in my first paper may be mentioned: First, the discovery near Sandy Point, in the Strait of Magellan, of an entirely new series of Tertiary deposits several hundred feet thick and underlying the *Patagonian beds*. These new Tertiary deposits have already been noticed by Dr. A. E. Ortmann and have been named by him the *Magellanian beds*.† Second, the discovery near Lake Pueyrredon of several distinct fossil-bearing horizons in the Cretaceous.

Chief among the changes which it now seems necessary to make regarding the geologic position and relations of the vari-

* See this Journal, vol. iv, pp. 327-354.

† See this Journal, vol. vi, 1898, pp. 478-482, and vol. viii, pp. 427-432.

ous sedimentary deposits as expressed in my former paper are: First, the age of the *Patagonian beds.* A study of the very extensive collections of invertebrate fossils which we now possess from the *typical Patagonian beds* makes it necessary to remove this entire series of strata from the Eocene, where we had formerly placed it, and to refer the rocks composing them to late Oligocene and early Miocene. Second, extensive observations in the *Patagonian* and *Supra-Patagonian beds* at many different and widely separated localities, has demonstrated beyond a doubt the identity of these two deposits, which were formerly supposed to be quite distinct and separated by a considerable period of time. Third, an interstratification has been observed between the upper Supra-Patagonian and lower Santa Cruz beds. This condition was first noticed and has always been maintained by Florentino and Carlos Ameghino. It was erroneously opposed by myself in my former paper, due to insufficient observations on my part at that time.

These additional observations and necessary corrections to my first paper, together with many other observations of scarcely less importance made during the past two years, render it advisable to record here the principal geologic features observed, and to give a correlation of the various sedimentary rocks now known in southern Patagonia based upon our present more advanced study of the fossils found in them and upon a comparison of these fossils with fossil forms from North America and Europe found in beds the age of which has been determined beyond a reasonable doubt both from paleontologic and stratigraphic evidences.

It will be the purpose of the present paper to give a brief description of the geology of southern Patagonia, together with a short discussion of the age of the various sedimentary deposits found there. A more detailed treatment of the geography, topography, stratigraphy and general geology of the region in question will be reserved for chapters under those heads, which will appear in one of a series of monographs to be issued by the department of geology and paleontology of Princeton University upon the natural history collections made by the University expeditions to Patagonia. This series of monographs is now in preparation, most of the material having already been placed in the hands of competent specialists in each department. Its early publication in a creditable manner has been made possible by the munificence of a friend of science.

That portion of Patagonia of which it is the purpose of this paper to treat lies beyond the 46th parallel of south latitude. A map of the region, including Tierra del Fuego and the

adjoining islands as far south as Cape Horn, has been prepared to accompany the present paper.

While most of the more important geographic features at present known are located on the map, especial attention has been given in its construction to indicate all those features which, though of little purely geographic interest, might prove of considerable value to any field geologist who in the future may wish to examine the same localities visited by myself for the purpose of verifying my observations. It is believed that with the text and accompanying map in hand it will not be a difficult matter for any fairly competent person to identify the different localities mentioned in the text or to verify the stratigraphic sections herein described.

The great value of explicit descriptions concerning the location of important geologic sections and of the surface exposures of new or little known geologic horizons, especially, as frequently happens, when such exposures are of limited area, must already have become apparent to working geologists everywhere. This is especially true in a little known and sparsely settled or entirely unsettled country like the interior of Patagonia. In the progress of my work in Patagonia I have been materially handicapped by the want of just such explicit and accurate descriptions of localities as I have myself always endeavored to give in all my published papers relating to the geology of the fossil fields of either North or South America.

In naming and defining a new geologic horizon it appears to me that the discoverer, if endowed with a true scientific spirit and considering the best interests of his chosen science, will be impelled to give at least one definite locality where the horizon may be found well represented and containing the fossils characteristic of it, when such fossils are known to exist anywhere in the newly-discovered beds. It should not be considered sufficient to say that certain beds are found represented "in the region of Lakes Viedma and San Martin" when the limits of these lakes are separated by a distance of more than 100 miles. Nor after describing an exceedingly important geological section is it enough to add that "this section is shown in a bluff in the region of Lakes Colhue and Musters," since the limits of these lakes, both of large size, are separated by long distances.

The want of more explicit information regarding localities, due perhaps to thoughtlessness on the part of Dr. Ameghino, has rendered much of my work in Patagonia necessarily a work of exploration and not so productive of paleontologic and geologic results as it would have been, had I been possessed of data enabling me to go directly to localities previously discovered by Señor Carlos Ameghino.

The map prepared and published by Dr. Francisco P. Moreno in the Geographical Journal of the Royal Geographical Society of London, accompanying a paper by the same author entitled "Explorations in Patagonia" and published in the September and October numbers of the same Journal for 1899, has served as the basis for the present map. It has been redrawn by Mr. Howard Logan, with the introduction of a few additions and corrections made by myself. The map is essentially the work of the Argentine Limit Commission under the direction of Dr. Moreno. While not complete it is fairly accurate and is by far the best of any of the maps yet published of this region.

Physiographic Features of Patagonia.

Before entering upon a discussion of the geology of Patagonia it may be well to refer briefly to the principal physiographic features of the country.* Patagonia and Tierra del Fuego are naturally divided into two sharply defined and easily characterized regions, a western, extremely mountainous, region and an eastern, comparatively level, plain. The mountains of the western region are formed by three parallel ranges separated by two deep, narrow, longitudinal valleys. Throughout the eastern plains region several features combine to break the monotony and lend variety to what would otherwise be an exceedingly dreary landscape. Chief among such features are the great transverse valleys that cross the Patagonian plains from east to west and form the principal drainage systems of those plains. These valleys frequently attain a depth near the Andes of more than 2000 feet below the surface of the neighboring plains. They are all true valleys of erosion, while the longitudinal valleys of the western mountainous region are of tectonic origin. It is along the bluffs of the sea and in the exposures over the slopes of these valleys and their less important tributaries that the best opportunities are offered for studying the geology of Patagonia.

Mesozoic.

Jurassic?—The oldest sedimentary rocks observed by the writer anywhere in Patagonia consist of a series of black, very hard but much fractured slates with remains of Ammonites fairly abundant but not sufficiently well preserved to admit of identification. These beds I have already noticed in my former paper on the geology of Patagonia, and have named

* For a further description of the geographic features of Patagonia, see paper on that subject by J. B. Hatcher in The National Geographic Magazine, Feb. 1900.

them the *Mayer River beds*, from the name of the river in the bluffs of which they were found. The localities where they may be observed were described in my first paper, and it is only necessary to remark here that neither their upper or lower limits have as yet been definitely determined. No additional evidence has been gained regarding their age, and they are provisionally referred to the Jurassic chiefly on account of the great thickness of the sedimentary rocks overlying them, which from the remains of Dinosaurs found somewhat abundantly in their upper members can scarcely be considered of more recent age than Cretaceous.

Cretaceous.

Pueyrredon Series.—Under this name I include some 800 feet of rocks observed in the vicinity of Lake Pueyrredon. The strata forming the *Pueyrredon Series* are immediately but unconformably overlaid by the variegated sandstones, *Arenisca Abigarradas beds* of Ameghino. The rocks of the *Pueyrredon series* are well exposed and may be conveniently studied on the left bank of Rio Tarde, some four miles above where that stream empties into the east end of Lake Pueyrredon. At about that distance from its mouth this small stream runs through a deep cañon, that has been cut in the eastern foothills of the Andes, and enters the broad level valley that extends eastward from the eastern extremity of the lake. Following the bed of the stream up the cañon to its source, there may be seen the most extensive and best exposed geologic section observed anywhere in Patagonia during my explorations in that country. Some 5,000 feet of sedimentary rocks are exposed in a continuous section extending from the Lower Cretaceous to late Pliocene deposits. Many distinct geologic horizons are represented and most of them are fortunately rich in fossil remains in an excellent state of preservation.

Gio beds.—Starting at the base of the section and at the mouth of the cañon, a deposit of soft green sands or marls about 100 feet thick are seen. Included in the green sands are several harder, brown layers, each about two feet thick and composed largely of shells of Exogyra. The proximity of this outcrop of these beds to Lake Gio and the Gio basin has suggested the name *Gio beds* for these green and brown sandstones. These beds dip gently to the southwest and their inclination, together with the rapid increase in the elevation of the bed of the stream as one proceeds up the cañon, soon brings the 100 feet* of strata composing them beneath the

* The thickness of the various deposits given in this section are based on barometric observations of altitudes: due allowance in each case was made for the dip of the different beds. While not absolutely correct, it is believed they are fairly accurate.

bottom of the cañon. Thus at a distance of only two or three hundred yards from the mouth of the cañon the top of the *Gio beds* appears at and passes beneath the bed of the stream.

Lower Conglomerates.—The *Gio beds* are immediately and apparently conformably overlaid by about 20 feet of hard, rather fine conglomerate, which will be designated the *Lower Conglomerate.* In this conglomerate were found occasional pieces of petrified wood filled with the shells of small boring mollusca. No other fossils were observed in this conglomerate.

Belgrano beds.—The conglomerates soon disappear beneath the bed of the stream and are seen to be conformably overlaid by about 300 feet of soft, greenish sandstones and clays, replaced toward the top by several layers of harder sandstones and impure limestones, each usually of only a few feet in thickness and appearing as ledges projecting from the side of the cañon. These 300 feet of strata we shall call the *Belgrano beds* from Lake and Mt. Belgrano, located some distance to the southward. These beds, especially toward the top of the series, are rich in the fossil remains of characteristic Mesozoic invertebrates. A few imperfect plant remains were also found, and a very few small, trituberculate teeth were discovered associated in the same rock with remains of Ammonites. These trituberculate teeth may perhaps pertain to mammals.

A considerable collection of invertebrates was made from the Belgrano beds at this locality and from another exposure of the same beds discovered some eight miles farther east. These collections, together with those made from the underlying *Lower Conglomerate* and *Gio beds*, have been placed in the hands of Dr. T. W. Stanton, who has already made a preliminary study of them and writes as follows: "Although not specifically identified, the relationships of many of the forms are such that there is no doubt of their Cretaceous age, and I am at present inclined to place them not earlier than about the middle of the Cretaceous, say Gault or Cenomanian. This is subject to revision, however. The Trigonias show close relationship with species from the Uitenhage beds of South Africa, which I believe are now generally assigned to the Lower Cretaceous." The Cretaceous age of these beds as determined by Stanton from a study of the invertebrate collections is significant, since Dr. Ameghino, after seeing two of the small teeth collected by myself from them, immediately referred this entire series of beds to the Jurassic.*

* See Sinopsis Geologica-Paleontologica por Florentino Ameghino (En Segundo Censo Nacional de la Republica Argontina, tomo 1, pp. 111-255, con 105 figs, Buenos Aires, 1898, en folio) Supplemento (Addiciones y Correcciones) Julio de 1899, p. 13.

Upper Conglomerates.—The *Belgrano beds* in the cañon of Rio Tarde are conformably overlaid by 330 feet of hard fine-grained red and variegated sandstone with occasional layers of clay ending above in a series of very hard fine conglomerates. No characteristic fossils were found in these beds, which may be called the *Upper Conglomerates* as distinguishing them from the *Lower Conglomerates* near the base of the series. A somewhat careful search for fossils was rewarded only by the discovery of a few imperfect plant remains and one or two casts of bivalve mollusca.

Thus far all the rocks of the entire series of strata through which we have passed in ascending the lower one and a half miles of the course of the cañon are conformable and evidently of marine origin. Taken together they constitute the *Pueyrredon Series*, with an aggregate thickness of from 750 to 800 feet.

The present surface distribution of rocks belonging to the *Pueyrredon Series*, known to the writer from personal observations, is of very limited extent and is confined to the lowermost 800 feet of strata exhibited in the lower course of the cañon of Rio Tarde and to other very limited exposures to be seen about eight miles to the eastward, in a small cañon cut in the surface of the first bench, which at this point has an altitude of some 200 feet above the bottom of the valley of Gio basin which extends eastward from Lake Pueyrredon. In this vicinity the bottom of the valley of Gio basin is occupied by a lake shown on the map as White Lake, and the exposures in question will be found at a distance of about two miles south of the western border of this lake. They are neither conspicuous nor extensive, but are exceedingly rich in well-preserved fossil remains. From verbal descriptions by Dr. F. P. Moreno, I infer that outcrops of the same series of beds may be seen in the region between Lakes Argentino and Viedma and lying west of the Rio Leon. Certain beds discovered by Dr. Rodolfo Hauthal in the vicinity of Last Hope Inlet, appear also to belong to this series.

Dr. Ameghino has on several occasions in his published papers referred to certain beds containing Cephalopod remains, in each instance almost invariably applying to them a different name and assigning them to the Jurassic without giving any reasons whatever for so doing. Since Dr. Ameghino gives no localities where his so-called *Jurassic beds* may be found and nowhere characterizes them, either by giving adequate descriptions of their lithological characters or specific and generic lists of the fossils contained in them, I have been unable to identify any of his Jurassic? horizons except the one referred to above in speaking of the small teeth collected by myself

and shown to Dr. Ameghino. This horizon, as has already been shown, belongs to the Cretaceous and not to the Jurassic. It seems probable that Dr. Ameghino has in each instance, as is evident in this one, when dealing with these marine Mesozoic horizons, based his remarks on the discoveries and observations of others and made his correlations to agree with his own preconceived ideas; instead of submitting such correlations to and abiding by the judgment of specialists in Mesozoic invertebrates.

Although the present known surface distribution of the rocks of the *Pueyrredon Series* is exceedingly limited, it is quite probable that future explorations will show that they are represented in a more or less continuous series of outcrops extending all along the eastern range of the southern Andes.

San Martin Series.—In this series it is proposed to include some 3,500 feet of Upper Cretaceous rocks, for the most part well represented at various places throughout southern Patagonia and more especially in the region lying directly east of Lake San Martin.

The Areniscas Abigarradas beds.—These beds, also frequently referred to as the *Variegated Sandstones*, lie at the base of the San Martin series. They are well represented in the bluffs along the south shore of the east end of Lake Pueyrredon and of the deep valley extending eastward from that lake. In the cañon of Rio Tarde they may be seen in a series of hard, well stratified sandstones 1,350 feet thick, overlying the *Upper Conglomerates* of the *Pueyrredon Series*, with which they appear slightly unconformable. They are usually fine-grained and of varying colors, with light pinks and pale greens predominating. They are exceedingly barren of fossils, a somewhat careful search at this and several other localities being rewarded by the discovery of only a few imperfect and uncharacteristic plant remains.

The rocks of the *Areniscas Abigarradas beds* have a much more extensive surface distribution than any of the other Cretaceous deposits of southern Patagonia. They appear over large areas all along the eastern base of the Andes and are known to cover a considerable portion of the interior plains region lying to the eastward of Lakes Pueyrredon and Buenos Ayres, extending even to the Atlantic coast, as may be observed at Port Desire. They also outcrop at intervals in the valley of San Julian, which extends inland for many miles from the head of the present bay of the same name.

Owing to the great thickness and uniform hardness of these sandstones as compared with most of the other sedimentary deposits of southern Patagonia, wherever found, they form

the principal and most striking topographic features of the region. In the cañon of the Rio Tarde they form vertical walls that for a considerable distance maintain an average height of more than 1,000 feet. They are referred to the Upper Cretaceous entirely upon stratigraphical evidences. Since they have been seen to rest unconformably upon the 330 feet of *Upper Conglomerates* which separate them from the underlying *Belgrano beds*, the latter, according to Stanton not older than *Gault* and perhaps *Cenomanian*, they must therefore be considered as belonging somewhere in the *Upper Cretaceous*.

Lower Lignite beds.—Under this head I include a series of beds consisting at the base chiefly of a fine, gray, volcanic ash deposit, passing upwards into a series of rather soft red and gray sandstones. These beds are entirely wanting in the Lake Pueyrredon and Rio Tarde sections, but may be seen in the bluffs on the south side of Mayer Basin, and especially on the left bank of the south fork of Rio Chico about three miles above Shell Gap. At this locality these beds have an estimated thickness of 1,500 feet and contain in great abundance partially lignitized, partially petrified trunks and branches of trees. In several instances vast accumulations of such tree trunks were observed, frequently forming the chief constituent of beds twenty to thirty feet thick and of unknown lateral extent.

I have nowhere observed the *Lower Lignite beds*, except about the headwaters of the south fork of the Rio Chico on the south side of Mayer Basin, where they unconformably *overlie the Variegated Sandstones*. Notwithstanding the exceedingly promising appearance of these lignite beds, an extended search in them for fossil remains was not rewarded by the discovery of any animal remains whatsoever. No definite opinion can at present be advanced as to their probable position in the Upper Cretaceous.

The Guaranitic beds.—The Guaranitic or Dinosaur beds consist of a series of soft, dark or mottled clays and shales with occasional layers of bright red, green and orange-colored materials of very fine grain. The finer of these colored deposits are mixed with grease and successfully used by the Tehuelche Indians as mineral paints, in the decoration of their person, wearing apparel and other articles.

The *Guaranitic beds*, like the underlying *Lower Lignite beds*, are entirely wanting in the Rio Tarde and Lake Pueyrredon sections, but are well represented in the region about the headwaters of the south fork of the Rio Chico and in the high bluffs on the south side of Mayer Basin between the sources of the last named stream and an eastern tributary of Mayer River

rising in the same range of bluffs. In this region these beds have an estimated thickness of 500 feet. They also occur in limited areas along the upper course of the Rio Chalia or Shehnen and at intervals over the central interior region lying between Port Desire and the eastern base of the Andes. In the latter region they are usually found occupying depressions eroded in the surface of the variegated sandstones and of certain porphyries and basalts of unknown age that occur here over considerable areas.

The Guaranitic beds contain fairly abundant Dinosaurian remains, but several weeks spent in them at different times and in various localities has resulted in a fruitless search for representatives of that rich, varied and highly specialized mammalian fauna which they are said by Dr. Florentino Ameghino to contain. On the other hand, Señor Carlos Ameghino, who has collected most of the material for his brother Florentino, assured the writer, during an interview with him in Santa Cruz, in July, 1898, that he had never found either Pyrotherium or any other representatives of the Pyrotherium fauna associated with Dinosaurian remains. Carlos Ameghino was very positive in his statements to me regarding this matter, and when shown Dr. Ameghino's statements on this subject as translated and published in The Geological Magazine of January, 1897, in an article entitled "Geology and Paleontology of Argentina," he said that there had been a mistake in the translation or that his brother had entirely mistaken his statements concerning the manner in which he had found the fossils of the respective faunas. He also informed me on the same occasion that previous to the expedition from which he had then but just returned to Santa Cruz, he had never found any mammalian remains whatsoever associated with the remains of Dinosaurs. On his last trip however he said he had found a few small multituberculate teeth associated with Dinosaurian remains in the *Guaranitic beds* on the upper course of the Rio Shehuen. These are Señor Carlos Ameghino's statements to me concerning the stratigraphic relations of these Dinosaurian and Mammalian faunas. It will be noticed that they agree on the whole with the published statements of Drs. Santiago Roth and Alcides Mercerat. They also explain why I have been unable to find the Pyrotherium fauna associated with the Dinosaurs. Such mistakes based on misunderstandings are always liable to occur, and are excusable where, as was the case in this instance, the author was recording not his own observations but the impressions left upon him by the narration of the observations of another, made in a region with which he was himself not only unfamiliar but entirely unacquainted.

The Guaranitic beds are referred to the Upper Cretaceous both upon stratigraphic and paleontologic evidences. Just

where they should be placed in that series cannot be determined until we know more of the Dinosaurs contained in them. At present it seems not improbable that they will prove to be the equivalent of the Laramie of North America, as they have long been considered by Dr. Ameghino and others.

With the *Guaranitic beds* we have reached the uppermost of the Mesozoic strata known not only to Patagonia but to South America, and assuming that they represent the Laramie we find the close of the *Mesozoic Era* in the southern hemisphere as in the northern marked by an abundance of gigantic and highly specialized Dinosaurs associated with the remains of an exceedingly scanty mammalian fauna, its representatives of small size, of generalized types and exhibiting even a less degree of differentiation and specialization than has been observed in the north.

Taken together the *Variegated Sandstones*, *Lower Lignites* and *Guaranitic beds* constitute the *San Martin Series*, of Upper Cretaceous age. The last two should perhaps be entirely separated from the Variegated Sandstones and considered as a distinct series, since they are unconformable with them and were very likely of largely fresh-water and aëolian origin, while the sandstones, on account of their vast extent and homogeneous nature, would seem to have been deposited in a great open body of water, probably marine, over which precisely the same relative conditions prevailed for an infinitely long period of time.

Tertiary.

For a long period following the deposition of the *Guarantic beds* all this region was elevated and subjected to erosion. During this long period of early Tertiary erosion the entire series of strata constituting the Guaranitic and Lower Lignite beds were in many places completely carried away, as has evidently been the case in the Lake Pueyrredon region; while in the vicinity of Lake San Martin and at various localities over the interior, remnants of the Guaranitic beds are still left having partially resisted the early Tertiary erosion to which they were subjected. The valleys which were then cut deep in the surface, frequently passing quite through the Guaranitic and Lower Lignite beds and into the rocks of the Variegated Sandstones, may now be seen in many localities filled with a series of Tertiary deposits varying in age from early Eocene to Pliocene. Such deposits have been sometimes of marine, sometimes of fresh-water or aëolian origin. The complex nature of the stratigraphy of the region in which they now occur, due to the eroded nature of the surface upon which they were laid down, has led Dr. Ameghino to consider such

Tertiary deposits as interstratified with the Guaranitic beds and Variegated Sandstones and therefore of Cretaceous age. Formerly Dr. Ameghino considered all of such Tertiary deposits as of one age and belonging to one series, which he designated as the *Pyrotherium beds.* In my former paper I pointed out that in the *Pyrotherium beds* of Ameghino there were represented two or more distinct horizons. I at the same time suggested that some of the fossil mammals described by Ameghino as from the *Pyrotherium beds* appeared to belong to a formation more recent than the *Santa Cruz beds.* Further explorations in Patagonia have only confirmed my former views and Dr. Ameghino has since partially adopted these views. He has now divided his Pyrotherium fauna into two faunas, referring one to the Middle and the other to the Upper Cretaceous. Unfortunately he has not yet recognized the true stratigraphic position of the beds in which the various faunas were found with reference to the *Guaranitic beds.* A further subdivison of this Pyrotherium fauna is necessary and a recognition of the *Miocene*, *Pliocene* and *Pleistocene* nature of several of the forms included in it. Among such Pleistocene forms will be found the large gravigrade edentate described by Ameghino as not distinguishable from Mylodon and more than likely Pyrotherium, which resembles very closely some of the larger Pleistocene herbivorous marsupials of Australia. Unfortunately I have not as yet been able to find any remains of Pyrotherium and have, therefore, been unable to determine its exact stratigraphic position. It is interesting to note, however, that Dr. Santiago Roth, who has spent two years collecting in beds which according to Ameghino contain his Pyrotherium fauna, has not found a single fragment of Pyrotherium, though Ameghino says that Pyrotherium is the most abundant and most characteristic fossil in the beds. Dr. Roth found other fossils of the Pyrotherium fauna fairly abundant.

The Pyrotherium beds, as that term has been used by Dr. Ameghino, includes a series of deposits of varying age from Eocene to Pleistocene. These deposits are of limited area and usually appear as yellow or ochre-colored sands and clays filling depressions eroded in the surface of the Guaranitic beds or occasionally of the Lower Lignites and Variegated Sandstones. The stratigraphic relations of these various Tertiary deposits to the Dinosaur and other Cretaceous beds of Patagonia are the same as the relations of the Equus to the Loup Fork and other Tertiary beds in our western States; and these somewhat obscure stratigraphic relations have led to the same confusion regarding the age and fauna of each that formerly existed concerning those of the Equus and Loup Fork beds.

Toward the close of the Eocene there began over southern Patagonia a period of subsidence, sufficient to bring most of that region beneath the surface of a shallow sea. Land areas continued to exist, however, along the Andes and an important land mass also extended over what is now the central interior plains region, to the eastward of Lakes Pueyrredon and Buenos Ayres. This land mass was perhaps connected with the continental land mass to the northward. From the commencement of this late Eocene subsidence until the middle of the Miocene, marine conditions, more or less extensive, prevailed continuously over portions of this region. Such marine conditions would progress or recede as the rate of subsidence exceeded, equalled or fell below the rate of sedimentation constantly going on over the bottom, and thus there was laid down over this region a series of deposits of marine and freshwater or aëolian origin, frequently interstratified, especially about the shores of the land masses. Such marine deposits are characterized everywhere by abundant remains of marine invertebrates of shallow water forms; while the lacustrine and aëolian deposits, though less rich in fossil remains, contain the bones and teeth of the animals inhabiting the lands adjacent to or over which they were deposited.

Eocene and Oligocene.

Magellanian Series.—This late Eocene subsidence commenced over the southern regions and gradually extended northward. In the vicinity of Punta Arenas there are represented several hundred feet of marine Tertiary deposits containing a marine fauna quite distinct and of decidedly older age than any of the marine Tertiary deposits known from the Atlantic coast region farther north. These marine deposits have been named by Dr. Ortmann the *Magellanian beds* and a brief description has been given by that author of the various species of marine invertebrates collected in them by the writer.

The type locality for the *Magellanian beds* may be considered to be the bluffs of the Rio de las Minas (Mines River on the map) that flows through the town of Punta Arenas and empties into the Strait of Magellan. These beds are especially well represented and extensively exposed on the left bank of that stream from the coal mines located about five miles above the town to a point some three miles lower down where the stream emerges from the cañon onto the level plain that extends from the foot of the hills to the beach north of the town. The Rio de las Minas has its source in the low range of mountains or hills separating the Magellan Strait from

Otway Water and forming the northern portion of the Brunswick peninsula, the southernmost point of the mainland of South America. The river has a nearly east and west course, and throughout its entire length the bluffs on either side of the stream are composed of sedimentary deposits of varying age from Upper Eocene to Pliocene, excepting certain bowlder deposits on the top of the mountains and other loess deposits in the valley, both of which are unfossiliferous and evidently of Pleistocene age.

Ascending the river from Punta Arenas, the Magellanian beds are first seen just where the stream emerges from the mountains about two miles above the town. At a short distance above this point a more important exposure may be seen on the left bank of the stream where the axis of a very gentle anticline is passed. From the axis of this anticline the strata on one side dip gently to the eastward or down stream and soon successively disappear beneath the bed of the stream, while on the other side they dip to the westward or up stream at an angle of perhaps five degrees. This westward inclination of the strata is continuous from the axis of the anticline to the source of the river except where affected by some local fault or landslide, as frequently happens above the coal mines and therefore in the beds above the Magellanian beds. No such faults were observed in the Magellanian beds below the mines.

In the bluff at the anticline, a few feet above the bed of the stream, there is a layer with numerous flattened concretions frequently a foot or two in diameter and of a light gray color, with fairly abundant leaf impressions, belonging principally to the genus *Fagus*. Some fifty feet higher up in the bluff another concretionary layer is encountered containing in great abundance the remains of marine invertebrates. In ascending the river some two or three miles until the coal mines are reached, several hundred feet of strata are passed through containing numerous fossil-bearing layers. Two such layers, each about ten or twenty feet thick, are especially prominent, appearing as bold projecting ledges due to the harder nature of the rocks composing them, and made up largely of the shells of various species of mollusca.

Dr. A. E. Ortmann, who has studied the invertebrate collections from these beds, has decided that they are not only quite distinct from the faunas of the *Patagonian* and *Supra-Patagonian beds* of the Atlantic coast farther north, but also that they differ entirely from the invertebrate faunas of the marine beds overlying the coal beds at this locality. He considers the fauna of the *Magellanian beds* as indicative of a decidedly greater age for these beds than should be accorded to the *Pata-*

gonian beds; he therefore considers the *Magellanian beds* as of *Late Eocene* or *Early Oligocene* age. I may also add that this paleontological evidence as to the age and position of the Magellanian beds is fully supported by stratigraphic evidences, since the same Coal Measures found at Punta Arenas have been observed farther north underlying beds that contain a fauna characteristic of the Patagonian beds. Moreover the beds which at Punta Arenas overlie the Coal Measures contain a fauna essentially characteristic of the Patagonian beds farther north.

The Magellanian beds at Punta Arenas are represented in the bluffs of the stream by perhaps 1,000 feet of strata, and the core from a hole sunk by a diamond drill to a depth of 360 feet in the bottom of the valley opposite the anticline already mentioned, did not pass through them. At present these beds have not been observed elsewhere than at the Punta Arenas locality. Very similar deposits were observed underlying certain lignites about the headwaters of the south fork of the Rio Chico, but it was not possible to secure other than fragmentary fossils from them. It is quite probable also that certain marine beds mentioned by Ameghino as occurring near Lake Argentina and about the source of the Rio Shehuen belong to the Magellanian beds. It may also be found advisable to correlate certain horizons in Dr. Ameghino's *Pyrotherium beds* with the Magellanian as representing lacustrine or aëolian deposits contemporaneous in origin with the marine beds farther south. In the excellent section of the Rio Tarde Cañon near Lake Pueyrredon the Magellanian beds and the overlying lignites are entirely wanting.

Upper Lignite beds.—In the Rio de las Minas section the Magellanian beds are conformably overlaid by a series of strata of unknown vertical extent, containing several veins of almost pure lignite varying from a few inches to ten or twelve feet in thickness. These beds, which constitute the upper limits of the *Magellanian Series*, have been observed at various places along the eastern Andes from Punta Arenas to the head of the Rio Chico north of Lake San Martin. They are probably of Middle or Upper Oligocene age.

Oligocene and Miocene.

Patagonian Series.—Under this head I shall include those deposits which have been commonly referred to by students of the geology of Patagonia under the names of *Patagonian, Supra-Patagonian* and *Santa Cruz beds.* On account of the fossils found in them and their great surface distribution throughout southern Patagonia, they are the most important of all the sedimentary rocks of this region.

Patagonian beds.—The type locality for the Patagonian beds may be considered as the bluffs of the Atlantic coast from Port Desire southward to the Mt. of Observation, some forty miles south of the Santa Cruz River. Anywhere along this coast within these limits the Patagonian beds may be found well represented and rich in the remains of fossil invertebrates. They appear to attain their maximum development in the region of San Julian, where they show a thickness above the water level of about 900 feet. From this point they dip gently to the southeast, so that at Coy Inlet their uppermost strata pass beneath the water level. The Patagonian beds are also known to extend along the Atlantic coast for a considerable distance north of Port Desire, and are found exposed in many localities in the bluffs of the streams throughout the interior of all that portion of southern Patagonia lying north of the Santa Cruz River. They may also be seen in a series of outcrops extending all along the eastern base of the Andes. In the section of the Rio de las Minas, they conformably overlie the Upper Lignites. They also appear in the bluffs near Lakes Argentina, Viedma and San Martin, at Shell Gap and various other places on the head of the Rio Chico and in the Pueyrredon and Rio Tarde sections, where they are 700 feet thick and rest directly upon the Variegated Sandstones or are separated from the latter by about fifty feet of columnar basalt. The entire series of strata constituting the Lower Lignites, Guaranitic and Magellanian beds and the Upper Lignites are wanting in the Pueyrredon region.

Ameghino has always considered the Patagonian and Supra-Patagonian beds as distinct and separated by a considerable period of time, and in my former paper I took the same view, since at that time I had worked but little in the typical *Patagonian beds*. During the last two years, however, I have given considerable attention to a study of the Patagonian beds in the type localities, and have made extensive collections of vertebrate and invertebrate fossils from them at Port San Julian and Darwin Station, some twenty miles south of that port, and about the mouth of the Santa Cruz River and the Mt. of Observation farther south on the Atlantic coast. These collections from the typical Patagonian beds I have also supplemented by collections made at many different localities throughout the interior region, and representing every conceivable horizon from the base to the top of the so-called Supra-Patagonian beds of that region, as well as at the Mt. of Observation. Among the localities from which such collections were made I may mention the following: the bluffs of the Santa Cruz River, source of Rio Shehuen, several localities between the latter stream and the Rio Chico, at Sierra Oveja

and Shell Gap and other places on the Rio Chico, Lake Pueyrredon, about the sources of Desire River, and at various places in the valley of San Julian. A study of the collections made at all of these and various other localities, with a careful regard for the different horizons from which the various collections were made, has demonstrated beyond a reasonable doubt the identity of the *Patagonian and Supra-Patagonian beds*, which do not represent distinct series of deposits of different age, but only different phases of the same series of strata. The differences in the fossils and lithological characters are in each instance due to the local conditions attending the deposition of the beds at the various localities in which they were found. The Patagonian beds represent areas covered by deeper waters, while the Supra-Patagonian beds represent the shallow water and littoral deposits. In the former the strata are more continuous and the rocks composing them are of a finer grain and with usually more calcareous material, while in the Supra-Patagonian phase the strata of sandstones, clays, etc. replace one another at frequent intervals along the same horizon, and are largely composed of coarse sands mingled with broken and ground fragments of shells in great abundance, frequently forming a genuine shell breccia.

Dr. Ameghino, in his latest contribution on the geology of this region, has not only separated the Supra-Patagonian beds from the Patagonian beds, but has also divided the latter into two formations, a lower *Piso Juliense* and an upper *Piso Leonense*. He thus has represented three distinct formations, which beginning below are called the *Juliense*, *Leonense* and *Superpatagonica*. Under each of these he gives a list of characteristic invertebrates as follows:

Piso Juliense.—Terebratula patagonica=(Terebratella p.). Bouchardia Zitteli, Rhynchonella plicigera = (R. nigricans), Pecten geminatus, Pecten praenuncius, Siphonalia noachina, Hypechinus patagonicus, Echinarachinus juliensis, Schizaster ameghinoi.

Piso Leonense.—Ostrea percrassa = (O. ingens), Perna quadrisulcata, Cucullæa alta, Turritella argentina, Struthiolaria ornata.

Superpatagonica.—Ostrea patagonica = (ingens, non d'Orb.), Pecten quemadensis = (P. geminatus), Cytherea splendida, Amathusia angulata, Voluta ameghinoi, Dentalium octocostatum.

Dr. Ortmann, who has studied our collections of Tertiary invertebrates from Patagonia and finds represented in them, with but one or two exceptions, every species hitherto reported from that region besides many additional ones, has made for me the following lists, showing the association which he has

already found to exist among species given by Dr. Ameghino as characteristic of the different beds, which that author has considered as distinct.

Among the collections from San Julian, the type locality for the Piso Juliense, he finds at Oven Point all the Juliense species but two (*Pecten prænuncius* and *Hypechinus patagonicus*) mingled with *Ostrea ingens*, a Leonense and Supra-patagonica species, while at Darwin Station, a higher horizon, these Juliense species are found: *Terebratella patagonica*, *Pecten geminatus*, *Siphonalia noachina*.

At the mouth of the Santa Cruz River, there are found mingled together in the same horizon all the species given by Ameghino as characteristic of his *Piso Leonense*, together with the following Juliense species: *Terebratella patagonica*, *Pecten geminatus*, *Schizaster ameghinoi* and these Supra-Patagonian forms: *Ostrea ingens*, *Amathusia angulata*, *Dentalium octocostatum*.

From the Mt. of Observation we have in the lowermost horizon *Cucullæa alta*, a Leonense species, while in the upper horizon or Supra-Patagonian beds, there are *Terebratella patagonica* and *Siphonalia noachina*, Juliense species, mingled with *Ostrea ingens*, a Leonense and Supra-Patagonian species, and *Voluta ameghinoi* and *Dentalium octocostatum*, Supra-Patagonian species.

At the base of the marine Tertiary in the Lake Pueyrredon section, which according to Ameghino should be Supra-Patagonian beds, we have the following five Juliense species, *Terebratella patagonica*, *Bouchardia Zittelli*, *Rhynchonella nigricans*, *Pecten geminatus*, *Echinarachinus juliense* and *Perna quadrisulcata*, a Leonense species, together with *Ostrea ingens*, a Leonense and Supra-Patagonian species.

In the uppermost of the Supra-Patagonian beds on the upper Rio Chalia and at Shell Gap or Rio Chico, the following three Juliense species, *Terebratella patagonica*, *Rhynchonella nigricans*, *Echinarachinus juliensis*, occur associated with *Turritella argentina*, a Leonense species, and *Ostrea ingens*, from the Leonense and Supra-Patagonian beds.

In one small block six inches in diameter, from the mouth of the Santa Cruz River, *Terebratella patagonica* and *Pecten geminatus*, Juliense species, were found associated with *Struthiolaria ornata*, which according to Ameghino is characteristic of the Piso Leonense.

In the above lists it will be noticed that only the characteristic species as given by Ameghino are included and it is seen that in every instance there has been found a mingling in the same horizon of these supposedly characteristic forms. While in some instances, as at Lake Pueyrredon, upper Rio Chalia

and Shell Gap, which according to Ameghino should be Supra-Patagonian beds, there is a preponderance of species given by him as characteristic of the Piso Juliense at the base of the Patagonian beds.

From a consideration of these facts regarding the association of fossils, it is clear that the terms *Piso Juliense* and *Piso Leonense* cannot be accepted, and also that the *Patagonian* and *Supra-Patagonian beds* are not distinct formations, but simply represent different phases of one and the same formation. The Patagonian phase prevails at the base of the series and the Supra-Patagonian at the top, but neither is limited to any definite horizon. I therefore discard the term Supra-Patagonian beds, and shall refer to strata formerly known under that name as the Supra-Patagonian phase of the Patagonian beds.

Age of the Patagonian beds.—Concerning the age of the Patagonian beds, there has been much difference of opinion. This difference has been due largely to careless collecting and imperfect observations as to their true stratigraphic position. During the first five years of their work on Patagonian geology and paleontology, the Ameghinos considered the *Patagonian beds* as overlying the *Santa Cruz beds.* They then placed the so-called Supra-Patagonian beds not only beneath the Patagonian beds, but separated from them by the entire series of strata composing the Santa Cruz beds. At that time they called the *Supra-Patagonian beds* the *Sub-Patagonian beds*, and the sequence as then determined by the Ameghinos in Patagonia was beginning below the *Sub-Patagonian beds*, the *Santa Cruz beds* and the *Patagonian beds.* In 1893, Senor Alcides Mercerat visited Patagonia and determined the true stratigraphic relations of these deposits, which he found to be identical with those suggested by Darwin a half century earlier. In 1894, in his fifth year of field work in Patagonia, Senor Carlos Ameghino, following Mercerat, was able to confirm the latter's determinations concerning the relative positions of these various formations, and the 2,500 feet of strata composing them were forthwith turned upside down, so to speak, by Dr. Ameghino, the Patagonian beds being placed at the base of the series instead of at the top and the Supra-Patagonian beds were removed from the bottom to the middle of the series and the sequence changed to *Patagonian*, *Supra-Patagonian* and *Santa Cruz beds*, passing from beneath upwards. This remarkable bit of stratigraphic juggling was accomplished in such a skillful manner by Dr. Ameghino that it became unnecessary for him to make any considerable changes in the age of the various beds to accommodate and harmonize with their altered and true stratigraphic relations. To

this discrepancy on the part of Dr. Ameghino is largely due the conflicting opinions at present expressed by him concerning the age of these various deposits.

The Patagonian beds are here placed in the Upper Oligocene and Lower Miocene on account of the evidences afforded by the marine invertebrates found in them. Moericke, Steinmann, Cossmann, Dall and others, all of whom have studied more or less material from these beds, are agreed in placing them in the Miocene. Dr. A. E. Ortmann, who is studying our collections in which there is represented much the most complete series yet brought together from the Tertiaries of Patagonia, is convinced that they are not older than uppermost Oligocene, and that they are chiefly Miocene. Dr. von Ihering, who studied the collections of Carlos Ameghino, relying upon his and Dr. Ameghino's stratigraphic determinations and differentiations, which as has been shown are only local developments and do not represent distinct horizons, has referred the Patagonian beds to the Upper Eocene and the so-called Supra-Patagonian beds to the Oligocene and Lower Miocene. Dr. Ameghino has himself considered the Patagonian beds as belonging to the Upper Cretaceous and Lower Eocene, assigning them this position, apparently, in order to accommodate his theory concerning the great antiquity of the overlying Santa Cruz beds.

In connection with the age of the Patagonian beds it is interesting to note the remarkably close relationship existing between this invertebrate fauna and the invertebrates from the Oamarú and Pareora Systems of New Zealand, which latter, according to Hutton, belong respectively to the Oligocene and Miocene. Dr. Ortmann has already found the following twelve identical species: *Rhynchonella squamosa* Hutt. (=costata Ten. Wood = pyxidata Dav.), *R. nigricans* (Sow.) (=plicigera v. Ihr.), *Magellania lenticularis* (Desh.) (=globosa v. Ihr), *Terebratella dorsata* (Gmel.), *Terebratella patagonica* (Sow.), *Ostrea ingens* Zitt. (=patagonica Aut. non d'Orb.= percrassa v. Ihr.=hatcheri and phillippi Ortm.), *Cucullæa alta* Sow., *Limopsis insolita* (Sow.), *Dentalium giganteum* Sow., *Scalaria rugulosa* Sow. (=lyrata and browni Zitt.), *Crepidula gregaria* Sow. (=incurva Zitt.), *Natica solida* Sow., and he informs me that this list will be very much increased and that many other species, while not precisely identical, show remarkably close relationships. The affinities exhibited by these two faunas are of interest not only for the evidence they afford concerning the age of the Patagonian beds, but also on account of the additional proof they furnish in favor of the theory of a former land, or at least exceedingly shallow sea, connecting New Zealand and other austral lands with South America.

The Santa Cruz beds.—Immediately and conformably overlying the Patagonian beds are the Santa Cruz beds, composed of a series of usually soft and light-colored sandstones and shales, rich in the remains of birds and mammals, but for the most part remarkably destitute of any molluscan or other invertebrate fossils, in marked contrast with the underlying beds. At the base the Santa Cruz beds are sometimes interstratified with the uppermost Patagonian beds. This condition was first recognized and pointed out by the Ameghinos. On my first expedition to Patagonia I was unable to find any conclusive evidence of such interstratification, and from certain apparent unconformities noticed at Shell Gap and Sierra Oveja on the Rio Chico, I concluded that the Santa Cruz beds were not interstratified with the Patagonian beds but were separated from them by a considerable time interval. Subsequent explorations have, however, convinced me of my error and I have been able to verify the observations of Señor Carlos Ameghino at the Mt. of Observation and to make similar observations in the Lake Pueyrredon section and at other localities throughout the interior.

The Santa Cruz beds are first seen in the Atlantic coast section near Mt. Observation south of the Santa Cruz River, where they form the summits of the higher bluffs bordering the coast. From this point southward they form a constantly increasing proportion of the total thickness of the bluffs of the sea until, on the south side of Coy Inlet, the entire series of strata forming the bluffs, with a maximum thickness of 600 feet, are composed of rocks of the Santa Cruz beds, which extend uninterruptedly to the mouth of the Gallegos River. It will thus be seen that the Santa Cruz beds appear continuously in the bluffs of the Atlantic coast from Cape Fairweather north for a distance of about 100 miles. They also cover the entire plains region between this coast line and the Andes, and toward the west they stretch far to the northward, extending even as far as the latitude of Lake Buenos Ayres, or 46° 30′ S.

The maximum development so far observed in the Santa Cruz beds may be seen in the Lake Pueyrredon and Rio Tarde section, where they overlie the Patagonian beds and show a thickness of 1,500 feet. From Lake Pueyrredon the Santa Cruz beds may be traced in an almost unbroken series of outcrops extending for more than 300 miles along the eastern range of the Andes.

From the entirely different character of the fossils encountered it is evident that there was a considerable change in the physical features of this region during the period which marked the close of the deposition of the Patagonian beds and

the beginning of the deposition of the Santa Cruz beds. About this time the gradual subsidence which had been going on during the deposition of the former series, became less rapid or ceased altogether, and the shallow sea in which those rocks were being deposited was converted into lowlands and estuaries which were at once invaded by the herds of animals inhabiting the adjacent lands, or others more distant, with which communications were then established. The remarkably rich mammalian fauna that at that time inhabited this region has left its remains in great abundance and often in a remarkably good state of preservation in the sandstones and clays of the Santa Cruz beds. Scarcely a foot of this entire 1,500 feet of sediment that is not fossiliferous, and seldom an exposure, however small in area, that will not yield a jaw or skull as a reward for even a superficial search. It is not to be understood that these deposits are everywhere equally rich in fossils, for like all other fossil fields, some localities are rich and some poor according as were the conditions during the deposition of the sediment favorable or not for the accumulation and preservation of animal remains.

Nothwithstanding the remarkable similarity of the rocks forming the Santa Cruz beds in the many exposures throughout their great geographical extent, it is evident that they were not deposited in an open fresh-water lake nor in a broad shallow sea of salt water. Not only are they in their typical development remarkably barren of the remains of either fresh or salt water invertebrates, but they contain the remains of land mammals in such abundance that it is absolutely impossible to conceive of these remains having been conveyed bodily into the middle of a great lake or ocean hundreds of miles in breadth. So far as is at present known, not a single mollusk shell, or fish, or crocodile bone or tooth has been found anywhere in the true Santa Cruz beds; although many of the strata are well adapted for the preservation of the remains of such animals, had they existed in any considerable numbers, as would undoubtedly have been the case had this region been covered during the period of their deposition by a great lake or other continuous body of water. Not only are the remains of land mammals abundant in many exposures, but in some instances the positions in which the skeletons are found are such as suggest that the animals lived and died in the immediate neighborhood where their remains now lie entombed.

One of the best localities for the collector of vertebrate fossils to be found anywhere in Patagonia is on the beach laid bare at low tide along the Atlantic coast between Coy Inlet and Cape Fairweather. On this beach the erosion accomplished by the rise and fall of the tides, which here have a maximum

difference of 46 feet, takes place along the bedding plains. Thus the same stratum frequently forms the surface over considerable areas, and the present slope of the beach is often for considerable distances precisely that of the inclination of the beds. Consequently in this region when a particularly rich fossiliferous horizon is found in the bluff, it will appear at its proper place on the beach owing to the southeasterly dip of the beds, and will form the surface over a considerable area often two or three miles in extent, each bedding plane appearing successively as the present surface of the beach, exposed to view only at low tide. When such localities were met with they were found to be extremely rich in fossils, and it was frequently possible while standing in one position to count a dozen or more skeletons, varying in completeness according as they had been more or less uncovered and washed away by the tides. Not only were the skeletons of these animals to be found, but in several places their fossil footprints were observed, and owing to the peculiarly favorable erosive action which prevails here, series of such footprints were occasionally seen extending for upwards of 100 feet, each track distinctly impressed so that it would have been possible to count the number of steps taken in covering a given distance and to measure the exact stride of the animal. All these conditions taken together bear conclusive evidence, it seems to me, that the skeletons belong to the same animals that made the footprints and therefore that these animals inhabited this very region during the time when the sediments now forming the rocks were being accumulated in the bottoms and over the flood plains of the swamps, small lakes, and tributary streams which existed here. Periodical variations in the amount of moisture, together with other conditions, would perhaps account for the lack of invertebrate remains.

Since the Santa Cruz beds conformably overlie the Patagonian beds, which have been shown to belong to the Upper Oligocene and Lower Miocene, the Santa Cruz beds must therefore belong to the Middle and Upper Miocene. This stratigraphical evidence of the age of these beds is strongly supported by the paleontological evidences afforded by the mammalian remains found in them. The highly specialized character of most of the genera can hardly be taken to indicate a greater antiquity for any of the strata than Middle Miocene.

Cape Fairweather beds.— The close of the Miocene was marked by a general subsidence, so that the sea again had access to this region, and during Pliocene times marine conditions prevailed here, resulting in the deposition of a series of deposits with a marine invertebrate fauna which originally covered almost the entire region, but has since been mostly removed and now appears over limited and widely separated areas, rest-

ing alike upon the rocks of the Patagonian and Santa Cruz beds or as has been occasionally observed upon some of the older basalts of the interior region.

The typical locality for the Cape Fairweather beds is near Cape Fairweather, where they may be seen at a distance of about two miles north of the Gallegos River, near the summit of the bluffs, unconformably overlying the Santa Cruz beds. They have also been observed near Darwin Station, south of San Julian, where they rest unconformably upon the Patagonian beds. They attain their maximum development in the region of Lake Pueyrredon, where they form the upper 300 feet of two isolated buttes on the top of the high bluff just south of the east end of the lake. At this locality they lie with apparent conformity upon the Santa Cruz beds, and the sedimentation appears to have been continuous at this place, at least, from the one to the other series.

Drs. H. A. Pilsbry and A. E. Ortmann, both of whom have studied our collections of invertebrates from these beds, are agreed as to their Pliocene age, which is moreover in strict accord with their stratigraphic position in relation to the Santa Cruz beds.

Distributed over almost the entire surface of the Patagonian plains and resting unconformably upon the various sedimentary deposits mentioned above, is the great *Shingle formation* of Pleistocene age and of combined ice and aqueous origin.

The following table is intended to show the sequence of the various sedimentary rocks of Patagonia and their age as at present indicated by paleontologic and stratigraphic evidences.

Pleistocene.	Shingle formation.
Pliocene.	Cape Fairweather beds.
Miocene.	Santa Cruz beds.
	Patagonian beds.
Oligocene.	Upper Lignites.
	Magellanian beds.
Eocene.	*Wanting.*
Cretaceous.	Guaranitic beds.
	Lower Lignites.
	Variegated Sandstones.
	Upper Conglomerates.
	Belgrano beds.
	Lower Conglomerates.
	Gio beds.
Jurassic ?	*Wanting.*
	Mayer River Shales.

Princeton, N. J., December 26, 1899.

Art. IX.—*Explorations of the "Albatross" in the Pacific. II. The Paumotus;* by Alexander Agassiz.

[*Letter No. 2*, dated Papeete Harbor, Tahiti Island, November 6, 1899, to Hon. Geooge M. Bowers, U. S. Commissioner of Fish and Fisheries, Washington, D. C., by Alexander Agassiz.]

During our stay in Papeete some time was spent in examining that part of the barrier reef of Tahiti which had been surveyed by the Challenger. We found the condition of the outer slope of the reef quite different from its description as given in the Challenger narrative. The growing corals were comparatively few in number, and the outer slope showed nothing but a mass of dead corals and dead coral bowlders beyond 16 or 17 fathoms, few living corals being observed beyond 10 to 12 fathoms.

We also made an expedition to Point Venus, to determine, if possible, the rate of growth of the corals on Dolphin Bank from the marks which had been placed on Point Venus by Wilkes, in 1839, and by MM. Le Clerk and de Bénazé, of the French navy, in 1869. We found the stones and marks as described, but in view of the nature and condition of Dolphin Bank, did not think it worth while to make a careful survey, as Captain Moser had intended to do. On examining Dolphin Bank in the steam launch I was greatly surprised to find that there were but few corals growing on it. I could see nothing but sparsely scattered heads, none larger than my fist! the top of the bank being entirely covered by Nullipores. We sounded across the bank in all possible directions and examined it thoroughly, and at the stage of water at which we sounded, found about 18 inches difference from the soundings indicated by the charts. It is also greatly to be regretted that Dolphin Bank was not examined, neither in 1839 nor in 1869, and notes made of what species of corals, if any, were growing on its surface; for an excellent opportunity has been lost to determine the growth of corals during a period of 60 years. The choice of this bank as a standard to determine the growth of corals was unfortunate, as it is in the midst of an area comparatively free from corals.

After refitting and coaling here, we left on the 5th October for a cruise in the Paumotus.

We steamed for Makatea, which we had visited on our way to Tahiti, and not only examined the island more in detail, but took a number of photographs of the cliffs of the east side, which, on our first trip, we passed late in the afternoon. We crossed the island from west to east, the path leading down from the summit of the cliffs bordering the island into a sink

at least 40 to 50 feet lower than the rim of either face of the island. The sink occupies a little more than one-third the length of the island. It is deeper at its southern extremity, where it is said to be 75 to 100 feet below the rim of the adjoining cliffs.

It is difficult to determine if this sink is the remnant of the former lagoon of the island, or of a sound formed during its elevation; or if it has been formed by the action of rain and atmospheric agencies. The amount of denudation and erosion to which this island has been subjected is very great, as is clearly indicated by the small cañons, pinnacles, and walls of limestone, as well as by the crevasses which occur in the surface of the basin in all directions. The extent to which this action has penetrated into the mass of the island is also plainly shown by the great number of caverns which crop out at all levels along the sea face of the cliffs, some of which are of great height, and extend as long galleries into the interior of the island. It is, of course, difficult, in the face of this extensive denudation and erosion, to state positively what may be part of the ancient lagoon, or sound, and what has been carried away by atmospheric and other agencies since the elevation of the island. At the south end of the island, which is lower than the northern part, there are only two distinct terraces, while at the northern end four terraces can be traced. The southern extremity, however, is still higher than the deepest part of the central sink of the island.

From Makatea, we visited Niau, Apataki, Tikei, Fakarava, Anaa, Tahanea, Raroia, Takume, Makemo, Tekokota, Hikueru, Marokau, Hao, Aki-Aki, Nukutavake, going as far east as Pinaki, when we turned westward again, to Nukutipipi.

On arriving at Pinaki we decided to give up the exploration of the eastern extremity of the Paumotus, and not to make our contemplated visit to the Gambier Islands, our time having been greatly curtailed by delays at Fakarava and Makemo, from bad weather and the non-arrival of our coal supply. We therefore reluctantly turned westward again and made for the Gloucester Islands. These, as well as Hereheretue, proved most interesting; they formed, as it were, an epitome of what we had seen on a gigantic scale in the larger atolls of the western and central Paumotus. We could see at a glance in such small atolls as Nukutipipi and Anu-Anurunga the connection between structural features which, in an atoll of 40 miles in length and from 10 to 15 miles in width, it was often difficult to determine.

We anchored in Fakarava and Makemo Lagoons, spending a number of days in both these atolls. We usually timed our visits to the islands where we could not anchor so as to spend

the day, or the greater part of the day, at these atolls, making our passages at night, and sounding whenever practicable on the way.

After leaving Tahiti we made over 100 soundings. These have shown in a general way that the western islands are probably all on a great plateau connected perhaps by the 800-fathom line. That such islands as Anaa are probably on spurs or independent smaller plateaux, separated from the main plateau by somewhat deeper water; the same may be the condition of Raroia and Takume, and of Hao and Amanu, while such smaller and isolated islands as Tikei, Aki-Aki, Nukutavake, and Pinaki, as well as the Gloucester islands, rise from greater depths and are isolated peaks. At any rate, these soundings indicate, as do the soundings off the Fijis, that atolls do not necessarily rise from very great depths, and that in this characteristic atoll district, atolls are found, it is true, with steep slopes, but rising from moderate depths. The slopes of these atolls would probably resemble in every respect the slopes of the elevated coralliferous limestone islands characteristic of the Lau Group in Fiji.

The deepest sounding among the Paumotus was on the line to the northward of Hereheretue in the direction of Mehetia, where we found a depth of 2524 fathoms, and a continuation of the red clay characterizing the soundings since we left Pinaki. In nearly all the soundings among the Paumotus, even at moderate depths not far from the atolls, we brought up manganese particles or small manganese nodules. The last haul, made in deep water on the way from Hereheretue, in 2440 fathoms, brought at least half a ton of manganese nodules, the bottom being red clay.

We have now steamed about 2500 miles among the Paumotus, and although we had not the advantage of the accurate surveys of the English Hydrographic charts, which made the exploration of Fiji so easy, yet from the structure of these atolls it was a comparatively simple task, by steaming around the islands and landing wherever practicable, to get a fairly good idea of their structure. We have seen nothing in this more extended examination of the group tending to show that there has anywhere been subsidence. On the contrary, the condition of the islands of the Paumotus cannot, it seems to me, be explained on any other theory except that they have been formed in an area of elevation; an area of elevation extending from Matahiva on the west to Pinaki in the east, and from the Gloucester islands on the south to Tikei on the north, although the islands in the line of Mangareva to Tahiti are separated from the other Paumotus by a deep channel, nearly 200 miles wide and more than 2400 fathoms in depth,

with scattered islets and atolls extending from Mangareva to Pinaki, and northward to Serle Island and beyond, islands which are not connected with the extensive plateau upon which the greater number of the Paumotu Islands to the westward of Hao rise.

All the islands we have examined are, without exception, formed of Tertiary coralliferous limestone which has been elevated to a greater or less extent above the level of the sea, and then planed down by atmospheric agencies and submarine erosion, the greatest elevation being at Makatea (about 230 feet), and at Niau, where the Tertiary coralliferous limestone does not rise to a greater height than 20 feet. At Rairoa it was 15 to 16 feet high. At other islands it could be traced only as forming the shore platform, from 50 to 150 feet wide, which forms the outer face of the Paumotus and is so characteristic a feature of the atolls of the group. In other parts the old ledge could be traced cropping up in the interior of the outer rim, or in the open cuts connecting the lagoon with the outer sea face of the atolls. Everywhere the space between the outcropping of the old ledge, as I will call the Tertiary coralliferous limestone, was filled with beach rock, or a pudding-stone, or with a breccia or conglomerate of coralliferous material consisting in part of fragments of the old ledge, and of fragments of recent corals and shells cemented together.

The appearance of the old ledge and of the modern reef rock is so strikingly different that it is very simple to distinguish the two, even where only comparatively small fragments are found.

We did not find in the Paumotus, as in Fiji, all possible stages of denudation and of submarine erosion between islands like Vatu Vara, Niau, Kambara, Fulanga, Ongea, Oneata, Ngele Levu, and Weilangilala, and atolls with a mere ring of surf to indicate their existence.

In the Paumotus the islands have been elevated to a very moderate height and probably to nearly the same height, for the old ledge forming the base of the modern structure is found exposed nearly everywhere at about low-water when it cannot be traced at a slightly greater elevation. This would readily account for the nearly uniform height of the islands throughout the group.

But there is another element which comes into play in this group, and has an important part in shaping the ultimate condition of these atolls. At the Fijis we have seen the submarine erosion continue until there is little left of many of the atolls beyond the merest small islet or rock to indicate its structure. In the Paumotus, in the great atolls which are evidently only the exposed summits of parts of ridges or spurs of an

extensive Tertiary coralliferous limestone bed, the rim of the atoll is, after having been denuded to the level of the sea, again built up from the material of its two faces, which is thrown up on the wide reef flats both from the sea face and from the lagoon side. We do not find in the Fijis such huge reef shelves to supply such masses of material from the breaking up of the outer and inner edges of the Tertiary limestone platforms, in addition to the fragments of the recent corals growing upon the flat and its edges, which, when dead, are thrown up and formed into shingle and sand to form a pudding-stone, or a conglomerate, or breccia, with the fragments of the old ledge on the top of the reef flats.

This pudding-stone, or beach rock, is found on all the reef flats of the islands of the group. It forms great bars, at right angles usually to the shore-line, and upon the sea face of these bars is thrown up coral shingle, both old and recent, which builds up short reaches of beaches separated by wide flats through which the sea rushes at high-water, or merely covers the flats at low tide; while on the lagoon side of the wide reef flats a similar process is going on, throwing up finer sand among the beach-rock bars and along their sides, and thus building up little by little; at first small sand bars, then larger bars, or islets, at right angles to the shore-line, and as they become larger by accretions from both sides, they finally form an island from 1,000 to 1,200 feet long, according to the width of the reef flat, extending from the lagoon edge of the flat to the sea face of the atoll. The sand bars, little by little, become covered with vegetation, and at some stages of tide appear like islands and islets situated a considerable distance within the lagoon. Whenever the material supplied both from the lagoon side and from the sea face is very abundant, the land ring becomes more or less solid, the islets become consolidated into islands, separated by narrow or wider cuts, until finally they form the larger islands which seem at first glance to form continuous land along the rim of the lagoon, but which are often seen to be separated according to local conditions by narrow cuts which finally allow no water to pass through and merely indicate the former separation of the various parts of the land.

In the lagoons of atolls of such great length as some of these of the Paumotus, like Rairoa, Fakarava, Makemo, and Hao—which are between 30 and 40 miles long, and others of less dimensions, considerable sea rises under the prevailing trades. The sea and wind generally follow the trend of the shores, both in the lagoon and along the sea face, so that the bars of beach rock act like buttresses and collect material at their inner and outer extremities, forming the sand bars and islets which eventually become the land rim of the lagoon.

When the material is not, from local causes, very abundant, or is washed out over the flats, there are fewer islands, and often these are but mere islets or bars for long reaches of shore, forming the characteristic weather faces of many of the lagoons.

Many of the lagoons are filled with shoals or ledges awash or a few feet above the sea level. These shoals are parts of the old ledge which have not as yet been eroded, and the disintegration of which has gone far to supply the material for the land of the outer rims of the atolls. In Fakarava there were no less than 36 islands and islets and ledges, parts of a former great flat, now broken up, existing parallel to the outer reef flat about 4 miles in the lagoon. Similar reef flats exist in Tahanea, where they form a secondary lagoon with 2 to 3 fathoms of water, extending nearly the whole length of the western face of the atoll. There are several large islands on this flat and at high water they would appear as the islands and islets of Fakarava do, as disconnected and planted in the lagoon itself. A secondary lagoon also exists in Ravahere, and in Anaa; in both these atolls the reef flat extends across one extremity of the lagoon and does not run parallel to the longer shore-line of the atoll.

The lagoons of these atolls have a general depth of 13 to 20 fathoms. In some cases they are somewhat deeper, as is stated, but there are no measurements, the greater depths, 30 fathoms or more, being due to orogenic conditions. Some of the atolls are quite shallow, as at Matahiva, as well as Pinaki, where the lagoon is not more than 2 to 3 fathoms, and Takume, where it is from 5 to 6 fathoms deep. Some of the smaller islets we visited, among which are Tikei, Aki-Aki, and Nukutavake, have no lagoons. The former has a small shallow sink in which fresh water collects, but the rim is only very slightly higher than the interior. The last two islets are apparently depressed in the center, 3 to 4 feet below the outer bank of sand which forms the rim (about 10 to 12 feet high) of the basin of the island. I was at first inclined to look upon these islands as examples of islands which had been cut down to the level of the sea and subsequently been built up by beach rock and sand in the manner described above. The existence of extensive sand dunes on two sides of the island at Pinaki, and of a large dune (estimated to be 35 feet high) on the south shore of Nikutavake, seems to indicate the possibility of there having been a shallow lagoon occupying the center of Aki-Aki and of Nukutavake, and that these lagoons were gradually filled by the sand dunes, much as Pinaki is filling now.

At Pinaki (Whitsunday Island), there is no doubt that the lagoon is rapidly filling from the sand blown in by the dunes. They are from 12 to 15 feet high, and are forcing their way in

towards the lagoon, killing the pandanus and whatever vegetation there is growing on the land rim of the lagoon. The dunes have probably filled also a second entrance to the lagoon indicated now only by a somewhat lower level of the land rim. Mr. Moore and Mr. Townsend, who went ashore at Pinaki, report that the lagoon is not more than 3 fathoms deep; they could wade over the greater part of it. Mr. Alexander counted no less than 116 islets in this small lagoon—less than a mile in diameter—islets formed of masses of dead Tridacna shells thrown up on ledge rock, on the slopes of which grew madrepores. The bottom of the lagoon is covered by Tridacna and masses of a species of Arca live near the edge; the intervening spaces being filled with nullipores. The entrance to the lagoon is perhaps 150 feet wide, and there is a cut through the beach rock covering the old ledge giving access to the sea into the lagoon at certain stages of the tide. The water in the lagoon is quite warm.

At Pinaki, as at other atolls and islets to the eastward, there are fewer cocoanuts than on the westward atolls, and the vegetation consists in great part of pandanus and puteau trees and the usual coral reef vegetation of the Paumotus and Fijis.

The only atoll we have seen, the lagoon of which is entirely shut off from the sea, is Niau. In this case the old ledge forming the rim of the land, which surrounds the nearly circular lagoon, is about a third of a mile in width and sufficiently high, 15 to 20 feet, to prevent any sea from having access to it except in case of a cyclone, as that of 1878, when the sea washed into the lagoon. The lagoon is shallow, of an average depth of about 3 fathoms, the deeper parts perhaps 5. The water is brackish, of a density of 1·0216 at 28° C. There are no corals living in it, but a species of mullet is found, as well as many marine shells, which, like those in the lagoons of San Salvador, in the Bahamas, are of diminutive size compared to their representatives living outside. The floor of the lagoon is covered with algæ. The lagoon has probably a slight connection with the sea, the water percolating through the limestone ring separating it from the outer reef flat. It is very difficult in this case to decide whether this lagoon has been gradually filled up after elevation, or whether it is merely a sink on a more or less uneven limestone surface.

Dana, and other writers on coral reefs, mention a great number of lagoons as being absolutely shut off from the sea. I take it these statements are due to their descriptions being taken from charts, many of which, as in the case of the Paumotus, are very defective. For nothing is easier than to pass at a short distance by the wide and narrow cuts which give in so many cases the freest access to the sea to the interior of the

lagoons, and described as closed because they have no boat passages. I could mention as instances of such lagoons, those of the atolls of Takume, Hikuero, Anaa, etc., which may be said to be closed, yet into which a huge volume of water is poured at every tide over low parts of the encircling reef flats.

The character of the coral reefs of the Paumotus is very different from that of other coral reef regions I have seen. Nowhere have I seen such a small number of genera, so many small species, and such stunted development of the corals. None of the great heads of the genera so characteristic of the West Indian regions, or of the Great Barrier Reef of Australia, are to be seen, with the exception of a couple of species of alcyonaria they are absent, so far as our experience shows, and there are but few sponges and gorgonians to be found among the corals. The bathymetrical limit of the reef-building coral seems to be about 20 to 22 fathoms, but nowhere have I seen such extraordinary development of incrusting nullipores as on the sea edge of the shore platforms of some of the Paumotus atolls, where they build up to a height often of 4 feet to form the outer edge of the secondary barrier reef so frequently seen along the reef faces of the Paumotus.

Judging from the temperatures taken at various points, 40° F. seems to be found quite generally at about 500 fathoms depth.

We made a number of surface hauls, as well as intermediate hauls with the tow nets, but obtained very little animal life. The poverty of the surface pelagic life and down to 300 fathoms is remarkable. I do not think I have ever sailed over so extensive an area as that of the Paumotus and observed so little surface life; on calm days, under the most favorable conditions, nothing could be seen with the naked eye, and at night there was little or no phosphorescence. Inside of the lagoons our hauls were equally barren.

The same paucity of animal life seemed to extend to the deepwater fauna. All the hauls we made off the islands, in from 600 to 1,000 fathoms, usually the most productive area of a sea slope, brought nothing, or so little that we came to grudge the time spent in trawling on the bottom, as well as towing on the surface or near it, a great contrast to the conditions in the Atlantic in similar latitudes, and very different from our anticipations.

For these reasons no attempt has thus far been made to make a trial of the deep sea pump while in such unproductive areas, and unfortunately while we were in the region of the equatorial currents the weather conditions were not suited for a trial of the apparatus.

ART. X. — *The Action of Ammonium Chloride upon Analcite and Leucite;* by F. W. CLARKE and GEORGE STEIGER.

IN a recent paper* upon the constitution of certain silicates, we showed that analcite, when heated with ammonium chloride, gave up a part of its soda, and absorbed ammonia to an appreciable extent. This result was so remarkable that it seemed to demand further investigation, upon material of different origin, and with variation in the details. The new experiments, which have led to highly interesting consequences, are now to be described.

The analcite previously studied was from Nova Scotia. To the kindness of President Regis Chauvenet of the State School of Mines we are indebted for a liberal supply of well-crystallized material from North Table Mountain, near Golden, Colorado, of which a uniform sample of about eighty grams was prepared. Upon this sample the present series of experiments has been conducted. Analysis of the analcite gave the following results:

Analysis.		Water by fractions.	
SiO_2	55·72	At 100°	·13
Al_2O_3	23·06	" 180°	·75
CaO	·17	" 260°	2·44
Na_2O	12·46	" 300°	1·28
H_2O at 100°	·13	" 350°	1·76
H_2O above 100°	8·26	" redness	2·03
	99·80	Total	8 39

Above a low red heat no further loss of weight was observed. Upon boiling the powdered mineral for fifteen minutes with a twenty-five per cent solution of sodium carbonate, 0·45 per cent of silica was dissolved. After ignition, 0·57 per cent was soluble, which is practically the same amount. No silica was split off by heating.

The experiments with ammonium chloride fall into two series. The first of these was conducted precisely as in our former investigation, by grinding the powdered mineral into an intimate mixture with four times its weight of chloride, and heating in an open crucible. In three cases the material, after volatilization of the ammonium chloride, was reground with a fresh amount of the salt, and then heated again. The temperature and duration of the experiments was purposely somewhat varied. After heating, the material was leached out with

* This Journal, October, 1899.

water, the sodium chloride which had been formed was estimated, and in the residue the fixed ammonia was determined.

In this series there were four experiments, with results as follows:

	Hours heated.	Temperature.	Soda removed.	Ammonia in residue.
A	28	300°	4·75	2·04
B	8½	350°	6·36	2·88
C	26	350°	3·76	1·72
D	5	340° to 380°	6·70	2·85

In our work upon the analcite from Nova Scotia the ammonia retained by the leached residue ranged from 2·03 to 2·36 per cent, while the extracted soda varied from 5·07 to 6·10. In two of the new experiments these figures are perceptibly exceeded, and they represent the shortest duration of heating. Prolonged heating seems to be undesirable, and to undo a part of the reaction which has taken place; otherwise the results obtained are of the same order as their predecessors. *About* one-half of the soda in the analcite is converted into chloride, while variable ammonia is retained.

In the second series of experiments a sealed tube was substituted for the open crucible. The powdered analcite was intimately ground with four times its weight of ammonium chloride, as before, and then heated to 350° in a tube furnace for from four to eleven hours. Under these conditions practically the whole of the soda in the mineral was converted into sodium chloride, while all of the liberated ammonia was absorbed by the residual silicate. Upon leaching the contents of the tube with water, to remove sodium and ammonium chlorides, a residue was obtained which exhibited constant composition whether dried at 100° or at the ordinary temperature of the air. Three samples of the residue were prepared and analyzed; other samples were partially examined and used for subsidiary experiments. The three analyses, lettered for future reference, were as follows, the analcite itself being included in the table for comparison.

	Analcite.	Residue A.	Residue B.	Residue C.
SiO_2	55·72	61·93	61·68	61·79
Al_2O_3	23·06	25·21	25·33	25·24
CaO	·17	----	----	----
Na_2O	12·46	·40	·22	·28
NH_3	----	7·23	6·95	7·71
H_2O	8·39	4·50	4·91	5·01
	99·80	99·27	99·09	100·03

Residue C was prepared with the greatest care, and was air dried. Exposed over sulphuric acid in a vacuum desiccator for

fourteen days, it lost in weight only 0·08 per cent. Tested for chlorine, only a slight trace could be recognized, but upon boiling for fifteen minutes with sodium carbonate solution it yielded 1·97 of soluble silica. After ignition only 1·70 of silica was soluble, or somewhat less than before. Upon heating to constant weight at 300°, only 0·46 per cent was lost; but at 350° it slowly decomposed, giving off ammonia. At 300° the compound is stable.

The 0·28 per cent of soda remaining in residue C may be regarded as representing unaltered analcite; doubtless coarser particles which escaped complete transformation. It corresponds to 1·98 per cent of analcite; which, together with the 1·97 of soluble silica, and the 0·46 of water lost below 300°, may be deducted from the substance in order to obtain the composition of the definite compound. The latter amounts to 94·72 per cent of the total residue, and agrees very nearly in composition with the formula

$$2NH_2.H_2O.Al_2O_3.4SiO_2.$$

Recalculating the 94·72 of residue to 100 per cent, we get the following comparison between analysis and theory.

	Found.	Calculated.
SiO_2	61·07	60·92
Al_2O_3	26·15	25·88
NH_3	8·14	8·63
H_2O	4·64	4·57
	100·00	100·00

Written in rational form the compound becomes equivalent to an anhydrous ammonium analcite,

$$NH_4AlSi_2O_6;$$

that is, analcite in which sodium has been replaced by ammonium. From this point of view the reaction between analcite and ammonium chloride becomes a simple case of double decomposition, and is perfectly intelligible. To establish this conclusion, however, corroborative experiments were necessary.

In the first place, the observed equivalency between the sodium lost and the ammonia gained might be due to a mere coincidence, and so far be illusory. One atom of sodium, taking chlorine from ammonium chloride, liberates one molecule of ammonia, the amount which the analcite residue has retained. Suppose more ammonia were present,—could it be absorbed?

To answer this question another tube was prepared, with the usual mixture of analcite and ammonium chloride. This was covered by a loose plug of glass wool, in front of which we placed enough pure lime to liberate about double the normal

amount of ammonia. The tube was then sealed, and heated to 350° as in the previous experiments. Upon opening the tube, a strong outrush of ammonia was noticed; but in the leached and thoroughly washed residue only 7·52 per cent of ammonia was found. This quantity agrees with that from the previous samples, and shows that the limit of the reaction has been practically reached. One molecule of ammonia is retained, and no more.

Still another experiment was tried upon a portion of the residue marked C. If the compound is really an ammonium salt, it should be decomposable by caustic soda in such a way as to reverse the reaction by which it had been obtained. The substance, however, is very insoluble, so that the reaction takes place slowly. To phenol phthalein it is absolutely neutral, and with Nessler's reagent it reacts only after long standing.

To settle the question a weighed portion of the compound was boiled in a distilling flask with a ten per cent solution of sodium hydroxide, to which water was added from time to time. The distillate was collected in a tube containing aqueous hydrochloric acid; and the ammonia which passed over was weighed, ultimately as chloroplatinate. By four hours boiling 6·90 per cent of ammonia was driven off and determined; and the residue remaining in the flask, after washing until no alkaline reaction could be detected in the wash-water, was examined for soda, of which 10·41 per cent was found. The anticipated reaction had taken place, although not completely; it was enough, however, to confirm our opinion, and to establish the nature of the new compound beyond reasonable doubt. Other confirmation was obtained later, from the study of leucite.

The foregoing paragraphs now enable us to understand a phenomenon which we observed in our work with the open crucible. In that case a partial reaction takes place between the analcite and the ammonium chloride, producing, as in the sealed tube, a mixture of an ammonium alumino-silicate with sodium chloride; the two substances being separable by leaching. But if, instead of leaching, the mixture be heated to full redness, ammonium chloride is reformed and given off, leaving a residue which contains little or no sodium chloride, and is wholly insoluble, or almost so, in water. That is, the reaction which occurs at 350° is reversed at the higher temperature, and anhydrous analcite, or an isomer of it, is regenerated. Ammonium and sodium again change places, and the original state of molecular equilibrium is restored.

What, now, is the nature of the product obtained in the open crucible, after sodium chloride has been removed? Is it a definite, intermediate compound, or an indeterminate mixture? In our former paper we adopted the first of these

alternatives, and assigned to the substance the formula $H_2Na_2Al_4Si_8O_{24}.NH_3$. In this expression we were influenced by the researches of Friedel, who had shown that ammonia could in part replace the "zeolitic" water of analcite; but it now appears that the phenomenon observed by him is quite distinct from that discovered by us, and, indeed, of an entirely different order. We may, therefore, in accordance with our new data, rearrange the formula; transforming it to that of an ammonium salt, $HNa_2NH_4Al_4Si_8O_{24}$, the agreement with the analytical figures being approximate only. The results obtained are not sharp enough for certainty.

This product we are now inclined to regard as a mixture, although it is not strictly intermediate between analcite and its final ammonium derivative. Only half of the eliminated sodium has been replaced by ammonium, while hydrogen, or water, makes up the deficiency. It seems probable that the reaction in the sealed tube and that in the open crucible are at first essentially the same; but that in the latter case secondary reactions follow which cause the variations in the final results. In the sealed tube, the element of pressure comes into play, and the reaction is complete. In the open crucible, pressure is lacking; some ammonia escapes fixation and reacts upon a part of the sodium chloride which was at first formed; hence the composition of the leached residue is essentially modified. This residue may be a definite compound; but the case in its favor is unproved, and the presumption is rather against it.

Between analcite and leucite the closest analogies have long been recognized. The two minerals have similar composition, they resemble each other in crystalline form, and they yield, upon alteration, products of the same order. Recently also, analcite, like leucite, has been identified as a not uncommon constituent of volcanic rocks; analcite-basalt being a good example. In view of these resemblances, it was plainly desirable to compare the minerals by means of the ammonium chloride reaction; a task which has been performed with satisfactory results.

In a preliminary experiment a sample of leucite, taken without regard to purity, was heated with ammonium chloride to 350° in a sealed tube. Potassium chloride was formed corresponding to 18·06 per cent of potash, and in the leached residue 6·90 per cent of ammonia was found. The foreseen reaction had occurred, and more careful work was accordingly undertaken.

Our material consisted of a large, irregular crystal of leucite from Vesuvius, which yielded about twenty grams of the pure mineral. This was ground to a uniform sample, and a portion of it was analyzed; the analysis will be given presently. The

sealed tube experiments were conducted precisely as in the case of analcite, and they confirmed both the preliminary test and our anticipations. Chlorides were formed equivalent to 18·53 per cent of potash, 1·08 of soda, and 0·08 of alumina; the reaction therefore was very nearly complete. The leached residue was then analyzed, and the data, compared with the analysis of the original mineral, were as follows:

	Leucite.	Residue.
SiO_2	55·40	60·63
Al_2O_3	23·69	26·44
CaO	·16	trace
K_2O	19·54	·50
Na_2O	1·25	·25
NH_3	----	7·35
H_2O	·24	5·17
	100·28	100·34

Leucite, then, gives the same reaction as analcite, and yields the same ammonium compound. A closer agreement in the composition of the latter could not reasonably be demanded. Ammonium leucite is formed in both cases, by ordinary double decomposition, in a state of approximate purity; the first silicate of ammonium, we think, which has ever been prepared. At the suggestion of Dr. F. K. Cameron an attempt was made to transform ammonium leucite into the corresponding lime salt, $CaAl_2Si_4O_{12}$, by fusion with calcium chloride. The ammonium leucite was mixed with a saturated solution of calcium chloride, which was evaporated to dryness, then heated gradually to dehydration, and finally fused. Ammonium chloride was given off and identified. Upon treating the fused mass with water, filtering, and thoroughly washing the residue, a white powder was obtained, which after drying at 100°, was analyzed. It was also examined microscopically by Mr. J. S. Diller, who found it to consist of apparently isotropic grains, showing traces of incipient crystallization. The following analysis is contrasted with the theoretical composition of calcium leucite, from which it varies considerably.

	Found.	Calculated.
SiO_2	54·35	60·30
Al_2O_3	26·23	25·63
CaO	17·38	14·07
K_2O	·16	----
Na_2O	·25	----
Cl	·28	----
Loss on ignition	1·24	----
	99·89	100·00

Evidently, the desired salt was not definitely obtained, and the product appears to be a mixture. The reaction, however, tends in the right direction, and deserves further study under other conditions. Probably the water which was present in the mixture of silicate and chloride took part in the changes produced; although of this we cannot be certain. It is interesting to note that the product obtained approximates in composition to the meteoritic mineral maskelynite, which is regarded as perhaps a calcium leucite by Groth.

The question now arises whether the observed reaction with ammonium chloride is limited to a few species or is fairly general. To test this point we have made preliminary experiments upon a number of other minerals, heating in a sealed tube to 350°, with the following results: The percentage of bases removed is calculated in each case upon the original minerals; that of the ammonia is the amount found in the leached and washed residue.

Natrolite.—17·56 per cent of soda removed, 8·29 of ammonia taken up.

Laumontite.—4·51 of lime and 0·35 of soda removed, 3·95 of ammonia absorbed.

Stilbite.—6·54 of lime and 1·31 of soda extracted, 5·36 of ammonia in the residue.

Chabazite.—4·37 of lime and 1·13 of soda removed, 4·55 of ammonia retained.

Thomsonite.—7·94 of lime and 3·40 of soda extracted, 4·01 of ammonia taken up.

Heulandite.—4·59 of lime and 1·59 of soda extracted, 3·64 of ammonia retained.

Apophyllite.—21·59 of lime and 5·18 of potash removed, 0·79 of ammonia in residue.

Pectolite.—20·72 of lime and 6·46 of soda extracted, 1·44 of ammonia retained.

Elaeolite.—2·25 of soda taken out, 0·74 of ammonia retained.

It will at once be seen that the reaction takes place in most cases, but with varying completeness. In some instances the decomposition is very slight, in others it is near the possible limit. In each case the ammonia of the residue was obtained by decomposing the material with hydrochloric acid, supersaturating with caustic soda, distilling into tubes containing hydrochloric acid, and final weighing as ammonium chloroplatinate. Each of the minerals mentioned is to be studied more thoroughly hereafter, and prehnite, sodalite, and possibly other silicates will be added to the list.

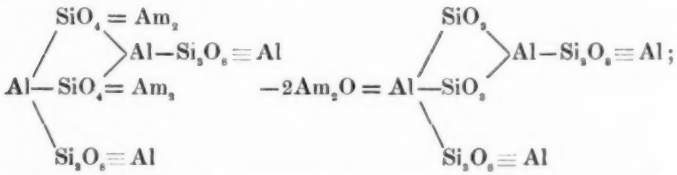
It is evident that all of the zeolites are well suited to this new method of study, and it is more than probable that the differences in the action of ammonium chloride upon them cor-

respond to differences in their chemical structure. But the reaction goes further than this, for it enables us to substitute in many minerals a volatile base for fixed bases, yielding silicates which split up on ignition in such a way as to shed light upon their molecular constitution.

For example, if ammonium leucite is a true metasilicate, a salt of the acid H_2SiO_3, it should break up, when ignited, in accordance with the following equation:

$$2NH_4Al(SiO_3)_2 = Al_2(SiO_3)_3 + 2NH_3 + H_2O + SiO_2;$$

that is, one-fourth of the silica ought to be set free, measurable by extraction with sodium carbonate solution. No such splitting off occurs, however; an ammonium leucite which already contained 1·97 per cent of soluble silica gave only 1·70 per cent after ignition; hence no additional silica had been liberated. We may conclude, therefore, that analcite and leucite are not true metasilicates but pseudo compounds; either salts of a polymeric metasilicic acid or mixtures of ortho-and tri-silicates as suggested in our former paper. The ammonium salt corresponding to such a mixture, when ignited, might be expected to give the following reaction:



a reaction which is in harmony with our experimental results. In it no free silica appears; and many, if not all, conditions of the problem are satisfied. Other formulæ, however, are possible; so that these offer merely one explanation of the phenomena, which one may or may not be the best.

ART. XI.—*Devonian Strata in Colorado;* by ARTHUR C. SPENCER.

Early recognition of Devonian.—The presence of Devonian strata in the San Juan region of Southwestern Colorado was announced in the report of F. M. Endlich, of the Hayden Survey, for the year 1874. The age determination, based upon a small collection of fossils, was made by F. B. Meek, the paleontologist of the Hayden Survey, and upon the evidence of this determination the geological map of Southwestern Colorado in the Hayden atlas, which appeared in 1877, had Devonian areas represented upon it. This work, however, has been either lost sight of, or discredited by recent writers upon the geology of the Rocky Mountains. In his paper upon "Orographic Movements in the Rocky Mountains," S. F. Emmons* indicates that of the areas represented upon the Hayden map as Devonian and Carboniferous, the lower part is known to be Silurian, though the facts on which this opinion was founded are not given. Again in a paper upon "Orographic and Structural Features of Rocky Mountain Geology," R. C. Hills† states, without qualification, that there are no recognizable Devonian sediments between the Silurian and Carboniferous in the San Juan region. He, however, expresses the belief that Devonian strata may yet be found in Southwestern Colorado.

Further information concerning the strata from which Endlich collected the fossils, pronounced by Meek to be Devonian, has recently been obtained by the Geological Survey party in charge of Dr. Whitman Cross, while engaged in areal mapping. The writer was a member of the party, both in 1897, when the fossiliferous limestones were found, and in 1898, when extensive collections were made. The actual localities which Endlich mentions have not been revisited as yet, but all the forms which he found, together with many others, have been obtained from beds in the Animas valley, which are evidently connected by continuous outcrop with the Devonian areas mapped by Endlich.

The fossils which Endlich collected have been preserved in the National Museum, where there are, also, other collections from beds in Central Colorado which now prove to be related to those of the San Juan region. These fossils have been made the subject of careful study by Dr. Geo. H. Girty of the U. S. Geological Survey, in connection with the determination of the more recent collections. The result of Dr. Girty's

* Bull. Geol. Soc. Am., i, p. 280. † Proc. Sci. Soc. Colo., iii, p. 366.

investigation has been to confirm Meek's opinion of the Devonian age of the fossils which were found by Endlich, and to establish the basis for a correlation of the Devonian of the San Juan region with strata in other parts of the State which have hitherto been included in the Lower Carboniferous.

Devonian in Southwestern Colorado.—The Devonian rocks are at present the oldest formations which are well authenticated in the San Juan region of Southwestern Colorado. Silurian was represented upon the Hayden map in Endlich's area, and though the areal distribution of the lower formations, as there shown, is very incorrect and gives no basis for a conclusion, it is thought from the text* that his Silurian is the basal quartzite of our section. The quartzite is wanting or of very limited development on the east side of the Animas river, where the Devonian was first discovered by Endlich, while it is very prominent in the vicinity of Cascade creek where his Silurian is indicated. The incompleteness of the Hayden map in regard to the basal portion of the sedimentary section is to be wondered at, since at no place where it has thus far been studied by us is the Devonian limestone absent between the crystalline basement and the rocks of well-recognized Carboniferous age.

The series below the Carboniferous consists typically of three members, a sandstone or quartzite at the base, a shale series, and a massive limestone. Of these, the lowest is frequently wanting through non-deposition, and the middle member is also sometimes very thin or entirely absent. The formation name, Ouray limestone, is proposed for the only member of the section which is definitely shown by its fossils to be of Devonian age, from the prominent occurrence in the vicinity of Ouray at the junction of Cañon creek with the Uncompaghre river. No names will be proposed for the lower formations at present, since, for purposes of mapping, it may prove necessary to include them under a single name.

Above the Devonian there is apparent conformity of deposition, but the occurrence of Upper Carboniferous fossils within a few feet of the Devonian limestone, and the absence of any fauna comparable with the Lower Carboniferous fauna from the Gunnison region and from Tourtelotte park, suggests a gap in deposition which represents the whole of the Lower Carboniferous. There is, however, a possibility that there may be a few feet of unfossiliferous limestone above the true Devonian, and not differentiated from it, which is really of Lower Carboniferous age. Such a lack of lithological difference would

* Hayden Geol. and Geog. Surv. of Terr., Report of F. M. Endlich for 1874, p. 210.

be quite analogous to the relations observed between the two formations in other places.

The most important areas of Devonian lie in the region south and west of the pre-Paleozoic core of the Needle Mountains. (Quartzite Mountains of the Hayden map.) The Ouray limestone has been noted as far east as Los Pinos river, and may be traced across the Florida river, and still westward to the Animas, where it was first observed by the writer. Detailed studies have not been made throughout this region, but the two lower members of the section are known to be locally absent. All of them are present along the west side of the Animas river for about twenty-five miles, from their southernmost outcrop about thirteen miles north of Durango, at Pinkerton Springs, to where they are covered by volcanic rocks of Tertiary age, just south of Silverton. In the vicinity of Ouray this formation rests upon the Algonkian rocks, the lower beds being absent. Southeast of Silverton, in Deer Park, and along the Bare creek trail, the quartzite is locally missing, while the shaly series is always present underneath the limestone. Still farther east and more to the north, upon the headwaters of the Lake Fork of the Gunnison river, none of the Devonian formations are found in place, but several huge blocks of quartzite and limestone like those of the Devonian were observed in the lower part of the great complex of effusive rocks which covers that region. Apparently these were wrenched off during some eruption and floated up by the fluid or viscous rhyolite lava, to be subsequently covered by streams of andesite and similar rhyolite. The Ouray limestone has also been identified in the marbleized limestones which appear near the center of the remarkable structural dome at Rico, some fifteen miles west of the Animas valley, opposite the Needle mountains. The known occurrences of the Devonian thus indicate its distribution over an area of approximately six hundred square miles in the San Juan region, with every reason for supposing an actual extent very much in excess of this.

The relations of the formations indicate an overlap, and, therefore, an advancing sea during the period of their deposition; however, the vertical element of the overlap was, at the most, not more than 200 feet. Thus, the relations of the sediments to their basement is indicative of a surface of very low relief in the pre-Devonian topography.

The quartzite which forms the basal member of the series here considered varies in thickness from zero to perhaps 100 feet. It is typically a massive white or reddish quartzite in which a well marked jointing is usually developed. It is composed almost entirely of quartz and its grain is rather fine and

uniform. Local variations are observed where the sandstone is flaggy, and conglomerates of medium coarseness are not rare in the lower part. Near the southernmost exposures in the vicinity of Rockwood, the contact with the basement rock, which at that place is granite, is marked by a basal conglomerate some six feet in thickness. The bowlders in this conglomerate, which have a diameter of six inches or more, are confined to the slight depressions in the floor. Above the conglomerate, and running over the tops of the knolls, there comes a fine-grained sandstone or quartzite. At the top of the quartzite there is an alteration of red or gray earthy limestone with reddish shales for a thickness of a few feet. The lowest of the earthy limestones is luted onto the topmost layer of the quartzite. The materials of this basal formation are remarkable in that they contain no fragments of feldspar though they rest directly upon a coarse granite, and that the bowlders were not derived from the rocks which immediately underlie the conglomerate. Such a formation is not the result of a rapidly advancing coast-line, but is rather the effect of activities which must have been long continued.

The occurrence of fish scales in the sandstone of the basal formation was reported by Endlich, and a single slab exhibiting fish remains was found by us in a talus pile at the base of a quartzite cliff near Rockwood, on the Silverton branch of the Denver and Rio Grande Railroad. The only other fossils from the quartzite are very imperfect impressions, which Mr. Walcott is inclined to refer to *Cruziana* or *Rusophycus*, supposed plants which are respectively of Silurian and Cambrian types.

The middle or shaly member varies in thickness from 25 to perhaps 100 feet in the Animas region. As already stated, it is missing in the Uncompahgre region. The shale series is very imperfectly exposed upon the west side of the Animas river, but upon the east side it may be studied at several places. It is especially well exposed in the high basins at the head of Deer Park, southeast of Silverton. It consists of calcareous marls and flaggy shales containing an occasional band of white sandstone. In color it has a somewhat variegated appearance, due to alternating bands of red, green and gray color. Wherever it is exposed, or wherever talus derived from it is found, it may be readily recognized from its general appearance. One of the most characteristic features is the appearance of slabs of sandy shale, which contain the curious markings that are known to represent crystals of halite, showing hopper-shaped crystals preserved as pseudomorphs in the substance of the rock.

The Ouray limestone is a massive limestone varying in thickness from 100 to 300 feet. In places the limestone is in one massive layer, while elsewhere it is in two or three heavy bands separated by greenish crumbling marls. The limestone is usually white, but is sometimes stained red or pink. Certain strata are somewhat coarsely crystalline, but as a rule the limestone is fine-grained. The chemical composition is variable, as is shown by the careful selection of certain portions for use in the smelter at Durango. The discarded portion is said to be too siliceous for metallurgical use.

The total thickness of the Devonian in the Animas region varies from 200 to nearly 500 feet, the former figure representing the usual development. At Ouray the thickness is not far from 200 feet.

The fossils which have enabled a determination of the age of this series are found in the limestone a short distance below the top. Neither the extreme upper or lower layers have thus far yielded organic remains. In the zone in which the shells occur there are several thin layers which are more coarsely crystalline than the mass of the limestone, and these are very frequently fossiliferous. The fossils are never prominent to casual observation, but when their horizon is once located and patiently searched, it usually proves to be quite productive. In some places, however, where many fossils are present, collecting proves unsatisfactory because of minute jointing which makes it impossible to secure perfect specimens. A list of the forms which have been recognized is here given:

Streptelasma sp.
Schizophoria striatula.
Orthothetes chemungensis var.
Productella semiglobosa.
Productella subalata?
Spirifer disjunctus var. *Animasensis.*
Spirifer coniculus.
Athyris coloradœnsis.
Athyris vittata var.
Camarotœchia (*Rhynconella*) Endlichi.
Camarotœchia contracta?
Mytilarca? sp.
Paracyclas sp.
Modiomorpha sp.
Allorisma sp.
Euomphalus clymenioides.
Euomphalus Decewyi.
Pleurotomaria sp.
Naticopsis? humilis.
Naticopsis gigantea.
Bellerophon sp.
Orthoceras sp. a.
Orthoceras sp. b.
Orthoceras sp. c.

Devonian Strata in Central Colorado.—In the course of the geological studies which have been made from time to time in Central Colorado, under the direction of Mr. S. F. Emmons of the U. S. Geological Survey, the determination of the presence or absence of Devonian rocks was a problem most difficult of satisfactory solution. Only the recent work at

Aspen has given any evidence of a positive nature, but a re-examination by Dr. Girty of the fossils collected at various localities in the central portion of the State has resulted in establishing the occurrence of Devonian strata in this region. It seems desirable to bring together in this place all the available information concerning the strata of Central Colorado which are now known to be of Devonian age. Some of the data have not been published hitherto.

At Leadville Emmons* was not able to find strata which could be referred with certainty to the Devonian. A meagre Silurian fauna was found in the lower part of the sedimentary series, while higher in the section, Carboniferous fossils were also found, but between these there was a considerable thickness of strata from which no organic remains were obtained. In the absence of adequate fossils, and in view of the opinion expressed by R. P. Whitfield,† that the characters of *Rhynconella Endlichi* were Carboniferous rather than Devonian, it was concluded that Devonian strata had not yet been found in Colorado, and it was thought advisable to apportion the lower part of the Paleozoic section between the Silurian and the Carboniferous. Between the white limestone of the Silurian and the blue limestone, which was classified as Lower Carboniferous because of the fossils which were found in its upper part, there is a quartzite which is typically about forty feet in thickness. This siliceous band was called the "Parting Quartzite" and it was given position as the uppermost member of the Silurian. Between it and the fossiliferous horizons of the blue limestone there are nearly 200 feet of limestone which are entirely unfossiliferous. It is this portion of the limestone immediately above the "Parting Quartzite" that probably corresponds with the Devonian of the Gunnison and Salida sections, described in what follows.

With the knowledge gained in the Leadville work, Mr. Emmons was able to establish the general correspondence of the Paleozoic rocks at several places adjacent, and his general results have been found correct by those who have made more detailed examinations under his direction.

During the field seasons of 1885–86, Mr. George H. Eldridge was engaged in the study of the stratified rocks of the Gunnison region. At this time, he also made careful sections and collections in the vicinity of Salida. At both places, Mr. Eldridge was able to recognize the "Parting Quartzite," and in the limestone strata which immediately overlie it, fossils

* Geology and Mining Industry of Leadville. Monograph U. S. Geol. Surv., xii, p. 56.

† Idem.

were found which had a Devonian aspect, but, in the absence of any stratigraphic criterion, the data were not considered to be sufficient to warrant the mapping or the description of the Devonian in the Anthracite-Crested Butte Folio, published in 1894. Part of the fossils which were collected in this region are in the National Museum and have been examined by Dr. Girty, who finds among them forms identical with those from the Devonian limestone from the San Juan region. The Devonian fauna is succeeded by a characteristic assemblage of Lower Carboniferous forms.

In the summer of 1889, at the instance of Mr. Emmons, a careful search for fossils was made by T. W. Stanton, in the lower Paleozoic strata near Glenwood Springs. *Rhynconella Endlichi* was one of the few forms collected, the rest being either Lower Carboniferous or pre-Devonian. At the time, this was taken as negative evidence in favor of the absence of Devonian, but since *Rhynconella Endlichi* is now known to be of that age, it seems probable that the Devonian limestones are present at this place. The "Parting Quartzite" is also probably present, though its true relations are obscured by the faulting which has taken place.*

At Aspen, Spurr† has described the same stratigraphic elements as those recognized at Leadville: the white limestone, the "Parting Quartzite," and the blue limestone are all present. Fish remains of a Devonian type, which were found in the "Parting Quartzite," furnish the basis for correlating this series with the Devonian of the Kanab valley in Southern Utah and Northern Arizona, as described by Walcott.‡ The stratigraphic position and lithology of the siliceous series in both regions are similar and have been considered by Spurr a sufficient basis of correlation.

The fossils occurring at Salida have been determined as follows:

Monotrypella sps. a, b, and c.
Schizophoria striatula.
Orthothetes Chemungensis.
Orthothetes Chemungensis var.
Productella subalata?
Productella subalata var.
Productella semiglobosa.
Spirifer disjunctus var. *Animasensis.*
Athyris Coloradoensis.
Camarotœchia (*Rhynconella*) *Endlichi.*
Camarotœchia contracta?
Euomphalus clymenioides.
Orthoceras sp. a.

* Opinion of Mr. Emmons in conversation.
† Monographs of U. S. Geol. Survey, xxxi, pp. 9–30.
‡ This Journal, xx, p. 224.

In the Gunnison region the following forms were found:

Streptelasma sp.
Chætetes sp.
Monotrypella sp. b.
Schizophoria striatula.
Orthis sp.
Orthothetes Chemungensis var.
Chonetes sp.
Productella semiglobosa.
Spirifer disjunctus var. *Animasensis.*
Athyris Coloradœnsis.
Camarotœchia (*Rhynconella*) *Endlichi.*
Camarotœchia contracta?
Naticopsis? humilis.

Other localities which are represented in the collections of the U. S. National Museum have yielded some of the forms listed above. The labels are not definite, but show the occurrence of the fauna over a wider area than that in which the section has been studied in detail. They are as follows: Massive limestone of White river, Colorado; Cañon of Cement creek, Colorado; Northwestern Colorado; Southwestern Colorado.

After a comparison of the fossils from the various localities, Dr. Girty says: "The strata from which these forms have been collected are without doubt of Devonian age. As they have essentially the same fauna, I refer them to the same horizon, which I take to be well up in the Devonian. In my opinion, it probably belongs below the Chemung, at about the base of the Upper or near the top of the Lower Devonian. While this fauna is clearly related to other fossil assemblages of our western Devonian, it cannot be said to be strictly identical with any one of them, for its common forms, *Spirifer disjunctus* var. *Animasensis*, *Athyris Coloradœnsis*, and *Camarotœchia Endlichi*, which, so far as I am aware, have not been found elsewhere, give it considerable individuality. Of the faunas with which I am familiar, it most closely resembles that described by Whiteaves from Hay river, Canada, and from other parts of the Mackenzie region."

Correlation.—The combined evidence furnished by paleontology and stratigraphy, as set forth in the preceding paragraphs, is thought to be sufficient to establish the practical equivalency of formations of Devonian age occurring in widely separated localities of Colorado, Utah and Arizona. The "Parting Quartzite" has been a datum of reference in all the geological investigations in the Central region of Colorado. With the discovery of its age as Devonian its equivalence with strata of that age in the Grand Cañon district was established, and now it is found to be represented in the San Juan region of Colorado. The evidence upon which this correlation rests, is the occurrence of fish remains of similar types in the three regions, and the corresponding position which the siliceous

series occupies below the Devonian limestone, in the San Juan region, and in certain localities in Central Colorado.

Fossils from the limestone immediately above the "Parting Quartzite" in the Gunnison region and at Salida are found to represent a fauna which is identical with that obtained from the Devonian limestone occurring above the siliceous series in the San Juan region. The correlation is thus firmly established, both as regards the limestone and the siliceous beds beneath it. It must be borne in mind, however, that in the San Juan region the lowest strata may be older than Devonian. There is a suggestion of this in the poorly preserved plants from the lower part of the quartzite, but the unity of the quartzite member as a whole is distinctly against this view.*

Following up the correlation brought out by Spurr between the "Parting Quartzite" of Central Colorado and the Devonian of the Grand Cañon region, it is of interest to note that the lower part of the Red Wall limestone of the Grand Cañon, below the part which contains the well recognized Lower Carboniferous forms, is unfossiliferous. It was suggested by Gilbert† that the base of the Red Wall Carboniferous limestone had possibly been placed so low that it might include the Devonian and even part of the Silurian. Devonian rocks have since been found below it,‡ and if the sequence is parallel in Colorado and the Grand Cañon district, it is very probable that the lower part of the Red Wall limestone is equivalent in age as well as in position to the Devonian limestone of Colorado.

If the correlations here suggested are correct, it appears that Devonian and associated strata were originally deposited over an extensive area in the Southern Rocky Mountain region, the boundaries of which are as yet entirely unknown.

U. S. Geological Survey, June, 1899.

* While there is, in the mind of the writer, no reason for doubting the equivalence of the siliceous formations which he correlates with the "Parting Quartzite," he does not accept as conclusive the evidence concerning their age. The fish remains have been pronounced of Devonian types, but in no case have they been specifically determinable, and it is to be remembered that the fishes from the Lower Silurian near Cañon City are of types not previously known to occur below the Devonian.

† U. S. Geol. Surv. W. of 100th Mer., iii, p. 178.

‡ C. D. Walcott, loc. cit.

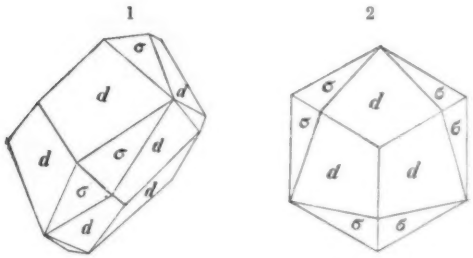
ART. XII. — *Sphalerite Crystals of a peculiar habit and with one New Form, from Galena, Kansas;* by AUSTIN F. ROGERS.*

THE sphalerite crystals usually found in the lead and zinc district of southeastern Kansas and southwestern Missouri are those of the ordinary types which are tetrahedral in aspect. The commonest of these types is that which exhibits the following combination: $o(11\bar{1})$ 1, $o_{,}(1\bar{1}1)$ $\bar{1}$, $a(100)$ *i-i*. Of these forms the negative tetrahedron $o_{,}$ is usually the predominant one. During the past summer some crystals of a peculiar habit were obtained from this region, a description of which seems worthy of publication. They were collected by the writer at the Tennessee Prairie mines five miles south of Galena, Kansas. I take pleasure in expressing my thanks to Mr. Clark, superintendent of the mines, for his kindness in allowing free access to the ore bins and dump piles.

The crystals are reddish-brown in color and vary in size from one-half to three centimeters in longest diameter. They are found as isolated crystals in a dark clayey siliceous matrix and show no attachment. The associated minerals include dolomite, pyrite, and chalcopyrite, the two former of which occur in considerable quantities.

The peculiarity of these crystals is that they are abnormally developed, being shortened in the direction of one of the octahedral interaxes. The predominant faces are those of the rhombic dodecahedron. In consequence of this abnormal development the crystals appear as combinations of a rhombohedron with the prism of the second order. On account of the presence of certain faces soon to be described the crystals have a decided hemimorphic aspect in the direction of the above mentioned axis. Here, then, we have an isometric crystal possessing apparent lower symmetry, namely, that of the rhombohedral-hemimorphic group. Figures 1 and 2 represent crystals of this habit. Figure 1 is an ordinary clinographic projection, which is shortened in the direction of the octahedral interaxis connecting the faces $(1\bar{1}1)$ and $(\bar{1}1\bar{1})$. Figure 2 is an orthographic projection with $(1\bar{1}1)$ as the plane of projection. Truncating half of the dodecahedral edges are the faces of a hemi-tetragonal trisoctahedron, the form $\sigma(833)$, $\frac{8}{3}\frac{8}{3}$ which seems to be new for sphalerite. As these faces and their combination edges with $d(110)$ are somewhat rounded and the faces are dull, no measurements with the reflecting

* Published by permission of the Director of the University Geological Survey of Kansas in advance of the final Report on Lead and Zinc.



goniometer were possible. The angle $\sigma \wedge \sigma$ over the edge $B(833 \wedge 8\bar{3}\bar{3})$ was measured with a contact goniometer giving the following results:

	Limits.	Average.	Calculated.
$\sigma \wedge \sigma (833 \wedge 8\bar{3}\bar{3})$ 12 measurements	55°–57°	55° 43′	55° 52½′

Angle measurements for the same form on crystals of normal habit from other localities in this district confirm these results. They are as follows:

	Limits.	Average.	Calculated.
$\sigma \wedge \sigma (833 \wedge 8\bar{3}\bar{3})$ 18 measurements	55°–56° 30′	55° 46′	55° 52½′

Occasionally the negative tetrahedron is present. The rough surface which it exhibits is characteristic of all the sphalerite crystals of the district.

Twins are more common than the simple crystals, which is also true of all the sphalerite crystals of the district. The twinning plane is the ordinary one for sphalerite, $o(111)1$. As no reëntrant angles are present, the twins may easily be mistaken for simple crystals, but they may be recognized as such by the fact that the prominent dodecahedral faces have no other dodecahedral faces parallel to them, and by the further fact that in the positive octants only two of the σ faces are united at one point while in the simple crystals three meet around this point.

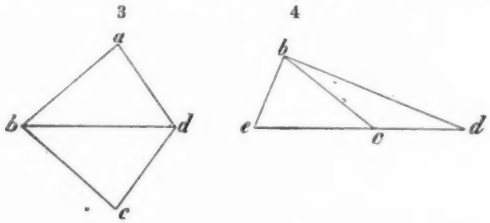
Becke* has shown that the positive and negative character of the forms on sphalerite may be distinguished by means of etch-figures. He used hydrochloric acid, but fortunately some of the crystals here described exhibit natural etch-figures on the faces of the dodecahedron. One large twinned crystal measuring 25^{mm} by 30^{mm} shows them very well.

The etch-figures consist of "etch-hills"† which in plan appear as monosymmetric four sided figures, fig. 3, with the

* Becke, Tschermak's Min. u. Petr. Mitth., vol. v, p. 457, 1883.

† For a recent discussion of the nomenclature of etch-figures see R. A. Daly, A Comparative Study of Etch-Figures; The Amphiboles and Pyroxenes. Proc. Am. Acad. of Arts and Sciences, vol. xxxiv, pp. 375 et seq.

axis of symmetry *bd* parallel to the shorter diagonal of the faces of the dodecahedron. Approximate measurements of the angles *abc* and *adc* gave 110° and 80° respectively. The solid angle at *b* is elevated above the general surface of the crystal, while the points *a*, *c*, and *d* are on this surface. In elevation, therefore, the etch-hills appear as in fig. 4. Here



the angle *ebd* is near 90°. The edges *ab* and *bc* and the solid angle at *b* are modified by minute faces which are not represented in the drawing. The "figure faces"* *abd* and *bcd* are highly polished and seem to reflect light at the same angle that the σ faces do, so that these figure-faces may perhaps be represented by the same symbol. The etch-figures resemble those described by Becke† except that the lines corresponding to *ab* and *bc* in fig. 3 are parallel to the edges of the dodecahedron while the lines in our figure are inclined about 20° thereto. In Becke's illustration the acute angle of the monosymmetric etch-figures points toward the negative octant. As this acute angle on our crystals points away from the σ faces, the latter are the faces of the positive hemi-tetragonal trisoctahedron $\sigma(833)$, $\frac{8}{3}\text{-}\frac{8}{3}$ and the prominent dodecahedral faces are (101), $(1\bar{1}0)$, and $(0\bar{1}1)$.

In conclusion I wish to thank Prof. E. Haworth for suggestions in the preparation of this paper.

Mineralogical Laboratory, University of Kansas,
Lawrence, Kansas, December, 1899.

* Daly, loc. cit.

† Becke, loc. cit. Figure copied by Tschermak, Lehrbuch der Mineralogie, p. 145.

Art. XIII.—*On the Estimation of Thallium as the acid and neutral Sulphates;* by Philip E. Browning.

[Contributions from the Kent Chemical Laboratory of Yale University—XCIII.]

Crookes* has shown that the salt obtained by heating thallous chloride with sulphuric acid until the excess of the latter is expelled and then raising the heat to redness has the constitution of a neutral sulphate.

He also found that continued heating did not result in any essential loss of weight, and suggested the possibility of applying this method of treatment to the estimation of thallium.

Castanjen† in a recent paper discusses thoroughly the compounds of thallium and confirms essentially the statements of Crookes in regard to the neutral sulphate, adding, however, the observation that on strong ignition in the air this salt tends to lose sulphuric acid. He also mentions in the same paper the acid sulphate and states that on heating it first melts and on continued heating gives off sulphuric acid, leaving the neutral sulphate.

The work to be described in this paper was undertaken to determine under what conditions the formation of these salts may be applied to the estimation of thallium. For the work a solution was made by dissolving a given amount of the nitrate in water and making up to a liter. The value of the solution was determined by precipitating measured and weighed amounts of this solution both as the iodide and chromate, as described in a previous paper.‡ Closely agreeing results by both methods were taken as the standard. Measured amounts of this solution were drawn from a burette into weighed platinum crucibles, and the weight taken as a check on the burette reading. To the solution in the crucible a few drops of sulphuric acid was added and the water removed by evaporation over a steam bath. The crucible was then removed to a radiator, consisting in this work of a conical iron cup, and heated at a temperature ranging from 220° C. to 240° C., until fuming ceased and the weight after half hour periods of heating remained constant. The crucibles were placed in a radiator upon a pipe stem triangle so that they were about 5^{cm} from the bottom, which was heated at low redness. A thermometer hung so that the bulb occupied the same position as the crucible gave the reading mentioned above.

As will be seen, the results obtained by this treatment agree closely with the calculated amounts of acid sulphate which

* Chem. News, viii, 243.
† This Journal, viii, 460.
‡ Jour. f. prakt. Chem., cii, 131.

should be formed. In several experiments this salt was dissolved in water and the sulphuric acid present in combination precipitated by barium nitrate. The results obtained agreed closely with the formula of the acid sulphate of thallium. Having obtained by the method described the acid sulphate, the crucibles were removed and heated carefully over a free flame to low redness, when, after a considerable evolution of sulphuric acid fumes, the weight again became constant, and the results showed a condition closely approximating to that of the neutral sulphate. In several of these experiments the sulphuric acid present in combination was determined and showed amounts closely agreeing with the constitution of the neutral sulphate.

	$TlHSO_4$ calculated. grm.	$TlHSO_4$ found. grm.	Error. grm.	Tl_2SO_4 calculated. grm.	Tl_2SO_4 found. grm.	Error. grm.
1	0·1605	0·1596	0·0009—	0·1344	0·1346	0·0002+
2	0·1611	0·1608	0·0003—	0·1349	0·1346	0·0003—
3	0·1608	0·1608	0·0000±	0·1347	0·1352	0·0005+
4	0·1612	0·1600	0·0012—	0·1350	0·1346	0·0004—
5	0·1602	0·1596	0·0006—	0·1341	0·1346	0·0005+
6	0·1608	0·1596	0·0012—			
7	0·1617	0·1604	0·0013—			
8	0·1608	0·1592	0·0016—	0·1347	0·1358	0·0011+
9	0·1609	0·1590	0·0019—	0·1348	0·1346	0·0002—

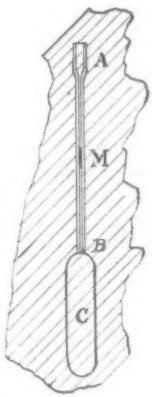
These results would seem to show that thallium may be estimated either as the acid sulphate or as the neutral sulphate by careful attention to the proper conditions of temperature.

ART. XIV.—*The Motion of a Submerged Index Thread of Mercury in the Lapse of Time;* by C. BARUS.

1. IF a short thread of mercury M is used under water as an index in the vertical stem of a bulb B, it is a common observation to find that the mercury will gradually creep downward into the bulb. Thus to take the case of an old Oersted piezometer bulb (capacity 35^{cm^3}) surmounted by a stem $0{\cdot}1^{cm}$ in diameter internally and exposed to variations of atmospheric temperature, the positions of the mercury meniscus were (neglecting intermediate observations)

1896, Feb. 8	9^h	Temp. 17° C.	Top meniscus	$1{\cdot}2^{cm}$	Bottom meniscus $3{\cdot}8^{cm}$
9	10^h	14°		3·1	5·7
10	10^h	15°		2·5	5·1
11	15^h	19°		2·1	4·7
12	12^h	17°		2·9	5·5

Since the thread returns to the same temperature on the 12th as on the 8th of February, 1896, the motion of the thread downward during the intervening 4 days and 3 hours (say 100 hours) was $1{\cdot}7^{cm}$.



From this it apparently follows that there must be leakage of liquid around the mercury and that a thin cylindrical shell of liquid may be sought for, between the thread of mercury and the inner wall of the glass stem. The viscosity of mercury being larger than that of water, this motion will persist in the main by shearing the shell of water in question. Under these circumstances (accepted as a first hypothesis) the condition of motion may be computed.

Let r be the radius of the tube, δr the thickness of the shell of water subjected to a cylindrical shear. Let l be the length of the thread of mercury, t the time in which the thread creeps down the length δl. Then the tangential stress shearing the film is per unit of area $\pi r^2 l\, 13{\cdot}6\, g/2\pi rl = 6700\, r$ nearly, when g is the acceleration of gravity. On the other hand, the rate at which the shear is increased is in the same *c.g.s.* units $\delta l/t\delta r$. Therefore if η be the viscosity of water at 20° (about ·01 say),

$$\delta r = \eta\, \delta l / 6700\, tr = {\cdot}0000015\, \delta l/tr, \text{ nearly.}$$

In the above piezometer $\delta l = 1{\cdot}7^{cm}$, $r = {\cdot}05^{cm}$, $t = 36\times10^4$ sec. Hence $\delta r = 1{\cdot}4\times10^{-10cm}$. If, therefore, the film were uniform,

and of the normal viscosity of water, its thickness would have to be much below even the diameter of the molecule of water.

This surprising result shows that the conditions assumed are not given. If water contributes to the motion, it must do so with so thin a film as to possess a viscosity enormously greater than the normal η assumed, or in other words, the difference between superficial and internal viscosity is here paramount. Again the result is a mixed phenomenon and it must be the object of experiment to disentangle the part played by capillarity from the part due to viscosity.

2. When in a room of variable temperature the thread of mercury is moved up and down in consequence of the thermal expansion of the water in the bulb, the effect is a tendency to moisten the tube or keep up a supply of water between mercury and glass. In the absence of such motion the film will gradually be squeezed out between mercury and glass whereupon the thread of mercury will hermetically seal the contents of the bulb. One would expect, therefore, that if the liquid is kept at constant or very slowly varying temperature, the mercury thread will be stationary. To test this I placed the above piezometer in a space of approximately constant temperature (i. e. varying very gradually from season to season). The results obtained were

1896, Feb. 14	Temp. 14·5° C.	Top 4·4^{cm}	Bottom 7·0^{cm}	Reduced mean position at 14° C.	5·9^{cm}
17	14·2	4·4	7·1		5·8
23	13·0	4·9	7·6		5·8
Mar. 15	14·5	5·3	7·9		6·8
Apr. 19	16·0	4·9	7·5		7·0
Aug. 5	19·9	5·2	7·8		8·9
1897, Feb. 6	14·0	13·0	Lost		14·3

Comparing this table with the last, it is seen that between Feb. 8, 1896, and Feb. 6, 1897, both at 14° C., the descent is about 12^{cm} for the year. The mean rate of descent for the year, however, is but ·0014^{cm} per hour as compared with ·017^{cm} per hour at the outset. Indeed, if the mean positions of the thread be reduced to a common temperature (see table), the curve obtained indicates an initial retardation of motion with time, succeeded by a marked acceleration of the motion on passing through the region of high summer temperatures; although the thread is but 2·6^{cm} long and the bulb quite submerged, some reason already exists to lead one to suspect viscous dilatations of the bulb.

3. At the circular edge of the meniscus three surfaces meet, and the difference of surface tensions of mercury-glass and water-glass must be equal to the resolved part of the surface tension of mercury-water. In other words, the resultant of surface tensions is normal to the glass surface at the edge in

question, thus admitting of a considerable contact angle. I am unable, however, to find satisfactory data for the stresses in question; but it is probable from the large values of surface tension involved that the rate at which water is withdrawn between mercury and glass is more rapid than the motions of the thread instanced above. The problem, therefore, now assumes a somewhat different form, namely, to so wet the glass by moving the mercury thread as to favor a supply of film between mercury and glass. I tried many methods to accomplish this. They were all negative as to results, and I will, therefore, merely describe one. The capillary tube AB (above figure), $\cdot 08^{cm}$ in diameter, surmounted by a cistern A, was provided at its lower end with a bulb C ($1\cdot 2^{cm}$ in diameter, $4\cdot 5^{cm}$ long), large enough to displace the thread M throughout its length (about $3\cdot 5^{cm}$) by reasonably heating the bulb in water baths (18° to 40°). A millimeter scale was attached to the stem and read off with a telescope. The tube was first placed in a special water bath of constant temperature (about 18°), and the position of the thread taken while a sensitive thermometer indicated the temperature of the bath. The tube was now removed and submerged successively in the two auxiliary water baths in question. In this way the thread was kept in continual motion at an average rate of about a centimeter in 10 sec., the operation being prolonged throughout 3,000 seconds. Finally the tube was returned to the normal water bath and the position of the thread read off at the temperature given by the sensitive thermometer. The bulb itself showed about $\cdot 2^{cm}$ per degree C, thus admitting of corrections. The results indicate a fall of less than $\cdot 05^{cm}$ for the 3000 seconds of motion. Inserting the superior limit in the above equation, a film having average thickness of $\delta r < 6 \times 10^{-10 cm}$ is deduced, in spite of the continued motion of the thread. This result, as absurdly small as the corresponding datum in § 1, shows the effect of motion of the kind applied to be insignificant.

4. Finally the endeavor was to be made to study the effects due to the volume viscosity of glass. The bulb of the above piezometer being 35^{cm^3} in capacity, a promising method would consist in reducing the volume to a very small value. Accordingly two tubes (Nos. II and III) with bulbs $\cdot 25^{cub\ cm}$ and $\cdot 40^{cub\ cm}$ in capacity, and stems respectively $\cdot 1^{cm}$ and $\cdot 2^{cm}$ in diameter, were selected. These were filled with pure water and a short thread of mercury ($4\cdot 7^{cm}$ and $4\cdot 2$ long in the two cases), inserted under water near the open ends of each. The tubes were now provided with glass millimeter scales and a thermometer, and then completely submerged in pure water contained in a long stand glass, closed with a rubber cork.

Observations of the lower and upper meniscus of each tube were taken from time to time in the course of about 4 years. Though placed in a vault, the seasonable variations of temperature could not be excluded. Change of temperature, however, was very gradual, and in view of the small bulbs and wide stems, the mercury thread was but slightly shifted. The data are recorded in the following table, and for brevity the mean positions of the threads (point midway between the upper and lower menisci) need only be given, as observed before and after April 19, 1896.

Time.	No. II.	No. III.	Temperature.
1896, Feb. 17	$-\cdot13^{cm}$	$-\cdot05^{cm}$	16° C.
Feb. 23	$-\cdot10$	$-\cdot05$	15
Mar. 15	$-\cdot03$	$-\cdot03$	17·5
April 19	$\pm\cdot00$	$\pm\cdot00$	19
Aug. 5	$+\cdot07$	$+\cdot11$	22·7
1897, Feb. 6	·24	·31	15·8
1899, Dec. 12	·92	·70	19·0

The mean positions are referred to an arbitrary cm. scale reading downward. Since the effect of temperature is slight, both series may be plotted to show their variations in the lapse of time. The data are found to be regular and consistent throughout the whole time of nearly 4 years. The larger thinner thread II shows more rapid motion than the shorter thicker thread III. Both move at a regularly retarded rate through infinite time, and there can be no further doubt that the cause of motion is the volume viscosity of the bulb, which is thinner and sustains slightly more pressure in case of II than in case of III. Taken together, the present rates under like conditions are strikingly less than the rate of motion for the above large piezometer bulb, which is again in accord with the more effective conditions for exhibiting volume viscosity in the latter case. Between April, 1896, and December, 1899, at 19° C., the mean motions of the threads were but 29×10^{-6} per hour for II and 22×10^{-6} per hour for III, as compared with the rates 17000×10^{-6} per hour and 1400×10^{-6} per hour (above, § 2), for the large bulb.

5. I was not prepared for the above results, not supposing that the viscous volume expansion of a totally submerged cold glass bulb, resulting from the pressure excess of a thread of mercury but $2\cdot6^{cm}$ long, would be of such marked value. Moreover this thread is filled in under water and in all cases retains a moist appearance, which may, however, only mean a clean surface of contact. Obviously, however, the surface viscosity of water, i. e. the change of viscosity with diminishing thickness of film can not be observed in this way. For the case of thin oils with small surface tension I am by no means sure that the case is hopeless and I have accordingly arranged a series of tubes with this end in view.

Brown University, Providence, R. I.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the third Radioactive substance in Pitchblende.*—In the belief that other radioactive substances occur in uraninite besides polonium and radium, Debierne, at the suggestion of M. and Mme. Curie, has made a further examination of this mineral in the laboratory of the Sorbonne; giving especial attention to those substances whose acid solutions are not precipitated by hydrogen sulphide, but which are completely precipitated by ammonia and ammonium sulphide. The crude material employed came from an Austrian chemical works where uranium compounds were made from pitchblende, and hence contained these compounds only in small quantities. Since the quantity of radioactive substance was very small, even in this residue, the several hundred kilograms used were first treated so as to eliminate polonium and radium as completely as possible. The larger portion of the ammonia precipitate was made up of alumina and iron oxide, though zinc, manganese, chromium, vanadium, uranium, titanium, columbium and tantalum were also present in minute quantities, as were also lanthanum, didymium, cerium and the yttrite earths. As the other elements were successively separated, the new substance became concentrated, the portion containing the titanium and its analogues showing radioactivity very intensely. A product was finally obtained giving the principal reactions of titanium, but which emitted extremely active rays, a fraction, by a rough determination, being estimated to be a hundred thousand times more active than uranium. While its chemical properties are entirely different from those of polonium and radium, its radiations are entirely comparable to those given out by these elements. They discharge electrified bodies, they excite phosphorescence of a barium-platinocyanide screen and they act on the photographic plate. The new substance, however, is not self-luminous, as Mme. Curie has shown radium to be.—*C. R.*, cxxix, 593, October, 1899. G. F. B.

2. *On the Spectrum of Radium.*—Having received at various times from M. and Mme. Curie specimens of barium chloride containing radium in progressively increasing quantities, Demarçay has submitted these to spectrum examination and finds not only that with the increase of radio-activity the line of wave length 3814·8, observed by him a year ago, becomes stronger, but that new lines also make their appearance. In the last specimen examined the radio-activity was about $1{\cdot}7 \times 10^4$ times that of uranium. Its spectrum was photographed in the ordinary way and was found to contain lines between wave lengths 5000 to 3500. This spectrum showed (1) a very intense and complete spectrum of barium; (2) the spectrum of the platinum electrodes

and of certain impurities, such as calcium and lead, the lines being very weak; and (3) fifteen new lines belonging to radium, some of which are as strong as the brightest barium lines. These lines have the following wave lengths, the numbers appended being the intensities, 16 being the brightest and 1 the feeblest: 4826·3 (10), 4726·9 (5), 4699·8 (3), 4692·1 (7), 4683·0 (14), 4641·9 (4), 4627·4 about, (4), 4600·3 (3), 4533·5 (9), 4458·0 about, (3), 4436·1 (8), 4364·2 (3), 4340·6 (12), 3814·7 (16), 3649·6 (12). At 4627·4 and 4458·0 are the centers of nebulous bands, the latter being the weaker. The lines are sharp and fine and recall those of barium. Other lines were observed, a dozen or more in number, but very faint. They will be measured when the radium is further purified. The author is now examining the less refrangible region.—*C. R.*, cxxix, 716, November, 1899. G. F. B.

3. *On the Atomic Mass of Radio-active Barium Chloride.*—Experiments have been made by Mme. CURIE to determine the atomic mass of the metal existing in the successive products of purification of the radio-active barium chloride. Two kilograms of this active chloride, extracted from half a ton of uranium residues were submitted to fractional crystallization, the activity being concentrated in the least soluble fractions. The chloride thus obtained was fractionally precipitated with alcohol. The most active material was contained in the precipitated portions. The atomic mass was determined in the anhydrous chloride in the usual way by precipitating the chlorine with silver nitrate. Each of these determinations was accompanied by a similar determination on inactive chloride, as a control. The radio-activity was simultaneously determined by measuring the current flowing between the two plates of a condenser 8^{cm} in diameter placed 3^{cm} apart, the differences of potential between these plates being 100 volts. The active material occupied a circular space 2^{cm} in diameter on the lower plate. The current produced by metallic uranium under these conditions is $0{\cdot}25 \times 10^{-11}$ ampere. With the successive fractions the following values were obtained:

$i \times 10^{-11}$ amperes	a	m	Ba
750	3000	140·0	138·1
1170	4700	140·9	137·6
1870	7500	145·8	137·8

Here i represents the current passing, a the radio-activity thus measured in terms of uranium taken as unity, m the atomic mass of the metal in the active chloride and Ba that of the metal in the inactive chloride used for comparison. It will be observed that a notable difference exists between the atomic mass of the active chloride and that of the ordinary chloride; and further that as the radio-activity increases, the atomic mass becomes greater also. Taken in connection with the spectrum results obtained by Demarçay as given above, it would seem that radium has a right to recognition as an element. The substances above measured were fractions examined at once after their preparation.

But it should be noted that the radio-activity of all these fractions, whether produced by crystallization as in the case of the chloride or by precipitation as in that of the sulphate and carbonate, increases very rapidly for several days after assuming the solid form; attaining at the end of some weeks in the case of the very active fractions a limiting value which may reach even five or six times the initial one. Experiments have not yet been made to fix the atomic mass of the substance used by Demarçay—which was 17000 times more active than uranium—for want of material. Evidently the atomic mass of radium is higher than that of barium.—*C. R.*, cxxix, 760, November, 1899. G. F. B.

4. *On Chemical Effects produced by Becquerel Rays.*—A yet more remarkable effect of the Becquerel rays has been noticed by M. and Mme. CURIE. They find that these rays emitted by very strongly radio-active barium salts are capable of transforming oxygen into ozone. When such a salt is preserved in a stoppered bottle, for a short time, there is perceived on opening the bottle a distinct odor of ozone; a fact first noted by Demarçay with the sample of active barium chloride sent him for his spectroscopic work. With the bottle open the odor is dissipated almost completely. But if the bottle be closed it regains its primitive intensity in ten or fifteen minutes. The production of ozone in this way was verified by the authors by means of iodide of starch paper which, placed before the mouth of the bottle, was distinctly colored. The tint is darker if the active substance is placed directly on the paper. Ordinary barium chloride produces no effect under these conditions. The radio-active substances required to produce this ozonizing effect are all very active and very luminous. But the effect seems more directly connected with the radio-activity than with the luminosity; a radium carbonate, though very luminous, producing less ozone than a radium chloride, much less luminous though more strongly radio-active. An analogous action of the Becquerel rays upon glass has also been observed by the authors. If a sample of a radium salt be preserved for a long time in a stoppered bottle, a violet coloration appears inside the glass and passes gradually through to the outside. With a very active material, the bottom of the bottle appears almost black in the course of twelve days. Even barium platinocyanide, when exposed to the action of radium, begins to turn first yellow and then brown, losing its power of phosphorescence; though by exposure to sunlight this power may be recovered. This yellowing effect can take place even through a plate of aluminum. If such a plate covered with the platinocyanide be placed above a radio-active salt, in the dark, the platinocyanide phosphoresces at first strongly, but gradually becomes brown and loses its brightness. But now if it be exposed to light the platinocyanide is partially regenerated, so that it now shines in the dark; thus showing the synthesis of a phosphorescent body of long duration by means of a fluorescent body and a radio-active one. Even crystals of the radiobarium

chloride, deposited from a hot saturated solution on cooling, which crystals are colorless, assume gradually a rose color; this color being assumed the more rapidly as the substance is more strongly radioactive. Since the transformation of oxygen into ozone requires a consumption of energy, the above production of ozone seems to prove in these rays a continuous evolution of energy.—*C. R.*, cxxix, 823, November, 1899. G. F. B.

5. *On the Chemical Action of X-Rays.*—The interesting results of M. and Mme. Curie just given have led VILLARD to publish some similar observations noticed sometime ago with X-rays. When a Crookes tube has been in use for some time the glass, as is well known, becomes violet in color in that portion above the plane of the anticathode, i. e., on the spot where it receives the cathodic rays. This region is struck both by the cathodic rays and by the X-rays simultaneously. To determine which produces the effect, the author surrounded the anticathode of a focus tube with a large glass tube, the interior walls of which could be protected against the cathode rays by a very thin plate of aluminum which is very transparent to the X-rays. A silhouette in opaque metal, as platinum for example, could be interposed in the path of these rays. After a half hour of action, the author observed that when no aluminum was interposed, the tube, if of flint glass, blackened strongly taking a bluish tint with a metallic luster; while if of ordinary glass it became simply brown; both being cases of ordinary cathode reduction such as is produced in a reducing flame. If the aluminum be interposed, however, it arrests the cathode rays and suppresses this reduction completely; and now only a violet coloration is developed, equally with both kinds of glass. This effect is evidently due to the X-rays. It is produced only above the plane of the anticathode and if a small plate of platinum be interposed, the protected region remains colorless. This phenomenon is certainly one of oxidation, the violet color being due probably to manganese. It establishes an interesting relation between X-rays and Becquerel rays.—*C. R.*, cxxix, 882, November, 1899. G. F. B.

6. *On the new Element Victorium.*—By means of long continued fractionations, by fusion and partial decomposition of the nitrates, by crystallization of the oxalates and by precipitation with potassium sulphate, resorted to in succession, CROOKES has succeeded in isolating from the earths of the cerium and yttrium groups a new element which he has called *victorium*. Victoria is an earth of a pale brown color, easily soluble in acids and less basic than yttria. If the oxide be assumed as Vc_2O_3, the atomic mass of victorium is about 117. The best material for obtaining its phosphorescence in a vacuum tube is, not the earth itself, but the anhydrous sulphate. The spectrum contains a pair of strong lines at 3120 and 3117 and fainter ones at 3219, 3064 and 3060.—*Proc. Roy. Soc.*, lxv, 237–243, 1899. G. F. B.

7. *The Elements of Physics*, for use in High Schools. By HENRY CREW, Ph.D., Professor of Physics in Northwestern

University. 8vo, pp. xiv, 347. New York, 1899. (The Macmillan Company.)—The starting point of this book, as the author tells us in his preface, is the essential unity of the Science of Physics. Being the science of matter and energy, its various subdivisions should obviously be so presented that the student passes by easy and natural steps from one to another, recognizing continually the great fact that while energy is conserved, it appears in various forms and gives rise to various phenomena. An examination of the book seems to show a good measure of success in this direction. The plan is excellent and quite novel for an elementary manual. The classification is good, the treatment of the subject is clear and exact, the illustrations are fresh and well selected. We think that Dr. Crew has produced a textbook which will not only render a service to the grade of schools for which it was written, but will find a place in other and higher institutions. G. F. B.

8. *Modes Opératoires des Essais du Commerce et de l'Industrie.* Leçons pratiques d'analyse chimique faites aux Laboratoires Bourbouze. Par L. Cuniasse et R. Zwilling, Chimistes-Experts de la Ville de Paris. Avec preface de M. Ch. Girard, Directeur du Laboratoire Municipal. 12mo, pp. viii, 302, Paris, 1900. (Georges Carré et C. Naud).—An analytical manual of commercial chemical analysis, giving the methods followed in the Bourbouze laboratory of the City of Paris. It is divided into two parts, the first treating of mineral analysis, the second of the analysis of organic substances. The methods seem to be well selected and clearly described. And the range of subjects treated is very considerable in view of the size of the volume. It will prove of much use to students in industrial chemistry, as the processes are modern and the details are well worked out. G. F. B.

9. *Radioactive Substances.*—M. Henri Becquerel has studied the phosphorescent effect of the radiation of radium. This substance was mixed with a few milligrams of barium chloride and the radiation was directed upon calcium, strontium sulphides, and rubies, diamonds, calc spar, fluorite, and hexagonal blende in a Becquerel phosphoroscope. It was found that all substances which became luminous under the X-rays also showed phosphorescence under the radiations from radium. A species of diamond which was very luminous under these radiations did not become luminous under the effect of the X-rays. Similar differences were observed with other substances. The author concludes that there is a loss of energy by radioactive substances.—*Comptes Rendus*, Dec. 4, 1899, pp. 912-917. J. T.

10. *Deviation of the Becquerel rays in the magnetic field.*—F. Giesel shows that these rays are deviated by magnets. A preparation of polonium was the source of the rays. Radium also showed the same phenomenon but not to so high a degree.—*Wied. Ann.*, No. 12, 1899, pp. 834-836. J. T.

11. *Velocity and susceptibility to magnetic action of the Cathode rays.*—In the same field which Professor J. J. Thomson has worked,* E. WIECHERT has made an elaborate investigation and believes that the discoveries of Lenard and Röntgen show the existence of an electrical atom of smaller dimensions than the chemical atom. This electrical atom has a negative charge. It is reasonable to suppose also that there are positive atoms of corresponding size. The deviation of the cathode rays by magnetic influence seems to the author far greater than if they consisted of streams of ordinary chemical atoms. On the emission hypothesis, therefore, it is necessary to suppose atoms of smaller size. The method of experimenting consisted largely in the use of Lecher's arrangement of circuits for determining wave lengths of electrical oscillations. A table of the values of the velocity v of the negative atoms is given in comparison with the velocity V of light. From this table it appears that the velocity v is about $\frac{1}{3}$ of that of light. The ratio of the electrical charge to the mass of the atom is of the order $4{\cdot}64.10^{17}$ or $3{\cdot}04.10^{17}$.— *Wied. Ann.*, No. 12, 1899, pp. 739–766. J. T.

12. *On the limits of hearing.*—R. KOENIG continues his investigations* of the upper limit of hearing and discusses the applicability of different methods of study. These methods consist in the use of rods vibrating transversely, rods vibrating longitudinally, vibrating plates and organ pipes, strings and membranes. By the use of Kundt's dust figures, the notes of tuning forks from c^4 to above f^7, or to 90,000 vibrations, can be determined with great accuracy. Strings and membranes are unsuitable for the determination of high notes. The paper concludes with a full summation of the results obtained.— *Wied. Ann.*, No. 12, 1899, pp. 721–738. J. T.

13. *Method of showing periodic current curves.*—Two papers have appeared on this subject in which the deviation of the cathode rays by an electromagnet is employed as the method of measurement. A bundle of cathode rays forms a luminous spot on a fluorescent screen and the position of this spot moves as the bundle is deviated periodically by the influence of an electromagnet. In fact this bundle constitutes an index of no weight and is well calculated to exhibit the periodical changes of the current which excites the electromagnet. The method is due to F. Braun (Wied. Ann., lx, p. 553, 1897). It is elaborated by J. Zenneck. The same number of Wiedemann's Annalen also contains a paper on the same method by A. WEHNELT and B. DONATH, who described a simple arrangement of the Braun cathode tube in combination with a photographic camera. The method is applied by the last-named writers to an investigation of the Wehnelt electrolytic interrupter, and they conclude that the Braun tube is suitable for quantitative measures of current and electromotive force curves.— *Wied. Ann.*, No. 12, 1899, 861–870. J. T.

* See this volume, p. 66.

II. Geology and Natural History.

1. *The Geological and Natural History Survey of Minnesota*, N. H. Winchell, State Geologist. *The Geology of Minnesota*, Vol. IV of the final report; by N. H. Winchell assisted by U. S. Grant, J. E. Todd, W. Upham and H. V. Winchell. St. Paul, 1899.—This volume deals with the geology of the northern third of the State of Minnesota, including all the counties bordering on Lake Superior and on the international boundary, as well as the great iron-producing sections of the State. The region to which it is devoted is an absorbingly interesting one. The interest is located at the two extremes of the geological scale. With the exception of a few scant remnants of a once extensive Cretaceous formation, all the older rocks of the region belong to the Archean or to the overlying Animikie and Keweenawan which are together designated by Winchell as "Taconic" contrary to common usage. Upon the glacially abraded surface of these older formations lies the late Pleistocene drift, and imposed indifferently upon the drift and older rocks are the features of the Glacial and post-Glacial lacustrine occupation. There are thus two classes of geologists who will be especially interested in the volume, viz: those who have worked in pre-Cambrian geology and those more particularly concerned with the problems of the Pleistocene. Of the thirty-two chapters contained in the volume six are devoted to Pleistocene and Recent geology, two by Upham and four by Todd. The last chapter of the volume is by H. V. Winchell and deals with "Minnesota Iron Mining, economically and statistically considered." The remaining twenty-five chapters deal chiefly with the geology of the older rocks. Thirteen of them are written by N. H. Winchell and twelve by Grant. The volume is large and important in appearance and has the attractiveness which graphic representations give to otherwise tedious geological descriptions, there being no less than 31 geologically colored plates, 48 photo-engravings, and 114 cuts in the volume. The volume does not, however, contain as much as its size would lead one to suppose. This is due to the method adopted for the presentation of the subject matter of the volume. The first twelve chapters give a description of this portion of the State by counties. In the majority of cases contiguous counties have the same or closely analogous geological features. Each county, however, or in some instances a group of counties, is written up as if the others were a *terra incognita*. In consequence of this there is a wearisome reiteration of the same statements without any comprehensive discussion of the region as a whole. This subdivision of a scientific work along the purely arbitrary lines of county boundaries can not be condoned. It throws upon the reader the task, which should clearly devolve upon the author, of subdividing the work along natural or rational lines and so massing the facts as to afford the broadest possible view of the questions discussed. As if the itera-

tion and incoherence unavoidable in the discussion of the geology by counties were not sufficiently bad, the evil is aggravated by the separate discussion of 19 distinct areas in as many chapters, each accompanied by a geological map. These areas are scattered over the region that has just been discussed by counties, and their treatment is not more exhaustive than that of the counties. The plates are admirable and tell their story well, except that geological sections are conspicuously absent; but they should have been used as illustrative material of a general discussion of the region, not made the basis of reducing that discussion to a series of platitudes. In point of arrangement of its subject matter, then, the book is weak. There is no treatment of the region by geological provinces such as one might reasonably expect to find in a final report on the areal geology of the State. The repetition of the same theme in a long array of chapters is very wearying to the reader.

In spite of the bad arrangement of the book, however, and in spite of the peculiarly antique, even Wernerian, tone of the preface to the volume, the work has many valuable contributions to geology within its covers. These consist partly of records of observations confirmatory of accepted generalizations, often tabulated, as in the case of hypsometric and glacial data, partly of observations not yet generalized and partly of new generalizations presented presumably for scientific criticism. The latter naturally make up the smallest but most important part of the report, and it is to some of these that we may address ourselves most profitably in the present brief review, leaving the data which are simply recorded, on the assumption that they have been printed for the sake of giving permanence to the record and not to invite comment.

The geology of the Archean as set forth in the report may be summarized as follows: The oldest rocks found in the region are more or less altered fragmentals and volcanics which are referred to the Keewatin. This is divided into two parts, designated as Lower and Upper Keewatin, with a well defined unconformity separating them. In the Lower Keewatin are incorporated a large volume of mica schists and feldspathic mica schists (often called gneisses) which the reviewer some years ago segregated from the Keewatin and designated the Coutchiching series. In the Lower Keewatin also are placed certain greenstones which are not regarded as altered volcanics but which (sad confession) are "supposed to represent the *cooled* original crust of the earth." This chilly proposition is thrown out nonchalantly in the preface but was probably frozen out of the body of the book as it is not further discussed. The rocks which underlie the Lower Keewatin wherever exposed, and the exposures are numerous and extensive, are granites or granitoid rocks with or without a gneissic structure, such as have been repeatedly mapped and designated as Laurentian. These granites and gneisses are intrusive in the

Lower Keewatin, so that the pre-Keewatin basement is nowhere observable, except for the above mentioned suggestions of a quite cold original crust of the earth. The base of the Upper Keewatin is marked by a well developed pebble-and-bowlder conglomerate which lies indifferently upon the Lower Keewatin and upon some of the granite which is intrusive in it.

The failure to recognize the Coutchiching as a series of metamorphic clastic strata of great volume distinct from the Keewatin is worthy of note, and arises from the difficulty, the great inherent difficulty of Archean Geology, of correlating formations on the basis of petrographical characters. The particular phase of that difficulty in the present instance is that schists similar to those of the Coutchiching, i. e., mica schists and feldspathic mica schists (gneisses so called), occur also in the Keewatin and the criteria for discriminating between the two have not yet been established. The mica schists are regarded simply as a result of the more intense metamorphism of the Keewatin. This view is advanced without attempt to explain the nature of the metamorphism which would convert the basic eruptives so characteristic of the Lower Keewatin into the very acid schists with which we are here concerned. The interesting fact comes out very clearly on nearly all the plates mapping the Archean, that there *is* a body of mica schists of very considerable volume intervening quite regularly between the greenish rocks of the Keewatin and the intrusive granites, just as is the case on Rainy Lake, where they were discriminated as a series of metamorphic sediments, which could be mapped and discussed as a constituent of the complex distinct from the Keewatin. The schists thus intervening between the greenstone of the Keewatin and the granite, although embraced in the Keewatin, are mapped in a distinct color which has, on many of the plates, a large breadth relatively to the greenstones and other constituents of the Keewatin. The fact that they are thus mapped where only the broadest kind of discrimination is attempted bespeaks for the mica schist formation an individuality and separateness such as were recognized on Rainy Lake. The fact, moreover, that the granite in several of the areas mapped comes directly against the greenstones of the Keewatin does not harmonize with the view that the mica schists are only more intensely altered portions of the Keewatin. It may be asked very pertinently, also, of the advocates of the new hypothesis whether the normal Keewatin is notably reduced in volume by the conversion of such a large fraction of it into mica schist?

It is but fair to state that Dr. Grant recognizes the Coutchiching as an individual series of the Archean complex though he complains of the difficulty of discriminating between it and the mica schists of the Keewatin. Mr. Winchell on the other hand declares that "under the term Keewatin are included all the clastics of the Archean." It seems to the writer that there is more to be gained for Archean geology in the present stage of investigation by discriminating as much as possible under as many names as may be needful for the purpose. It will be time enough to drop

out superfluous names and select our comprehensive terms, such as would embrace *all* the clastics of any part of the Archean, after a few more *final* reports have been written. When the history of the Archean has been worked out as fully as may be, the names of *all* the clastic formations comprised in it will be too numerous to refer to except by comprehensive designations and groupings, but to say that "under the term Keewatin are included all the clastics of the Archean" is simply to set up Keewatin as a synonym for Archean, which of course is not Mr. Winchell's intention.

Another point of prime importance for Archean geology is the segregation of the upper from the lower Keewatin, by the recognition of the significance of the conglomerate at the base of the upper series. The true position of this conglomerate as marking an unconformity *within* the Archean was pointed out by the writer several years ago and the work of the Minnesota Survey sustains this view. Upper and lower Keewatin certainly both antedate the great hiatus which separates the Archean from the Animikie. In this two-fold subdivision of the Keewatin we very probably have the correlatives of the upper and lower Huronian of Lake Huron, especially in the light of Coleman's more recent observations. This correlation if well founded would greatly simplify the present tangled condition of Lake Superior geology. If the upper Keewatin be the correlative of the upper Huronian, as seems to the writer extremely probable, we must relegate to limbo that far-fetched correlation of the Animikie and upper Huronian, which has become intrenched, as only error can, in the literature of pre-Cambrian geology of the past decade. It is this supposed equivalence of the Animikie and upper Huronian which has led to the remarkable attempt to pull the Huronian out of the Archean and make it a subdivision of the Algonkian. This idea once happily demolished it is to be hoped that the Algonkian will fall into its proper place in taxonomy as a designation for an assemblage of rocks between the Archean and the Cambrian, and that it will no longer like Pharaoh's lean kine attempt to fatten itself by devouring the plump and well-favored formations of the Archean.

Upon the worn surface of this Archean complex rests the Animikie in little disturbed attitudes, a purely clastic series, near the base of which occur the ore bodies of the now famous Mesabi iron range, the origin of which has been so ably discussed by Spurr in an earlier publication of the Survey. The Animikie embraces the following four subdivisions in ascending order: 1. Quartzite formation. 2. Taconite or iron-bearing formation, varying in character from hematite to a rock which has been identified as an altered greensand. 3. Black slate formation. 4. Graywacke slate formation. The trap sheets so common in the Animikie as intercalations in the formations above enumerated, which a few years ago were commonly supposed to be contemporaneous lava flows, are recognized in their true character as intrusive sills. The faulting which characterizes the Animikie in

the region of the international boundary is recognized only in a tentative way.

Upon the Animikie rests the Keweenawan, and in the discussion of this series certain new propositions of interest are advanced. It may be said in general that the Keweenawan of Minnesota is almost wholly made up of volcanics and the intrusives which traverse them with but a small admixture of sedimentary strata. The series is thus in strong contrast to the underlying Animikie. A formation of conglomerate with sandstone or quartzite has long been recognized in the Thunder Bay region as the base of the Keweenawan (Nipigon series). The Minnesota Survey finds that Duluth gabbro, the "red rock" and certain lavas, e. g., the Beaver Bay diabase, all of which have been referred to as Keweenawan, seem to antedate the conglomerate (Puckwunge). It therefore divides the Keweenawan into two parts, viz: The Cabotian which includes all that precedes the conglomerate and the Manitou including the conglomerate and later formations. In making this discrimination Mr. Winchell is evidently in a quandary whether to put his Cabotian in the Animikie or keep it in the Keweenawan. He expresses his opinion that the Animikie graded gradually into Keweenawan, and that in the Keweenawan there was a profound erosion interval represented by the Puckwunge conglomerate. This seems to the writer an indefensible position to assume. The logical thing to do is to place anything that grades into the Animikie and antedates such an unconformity into the Animikie. But it is not at all clear that any such reconstruction of the Animikie is necessary. It does not seem, for instance, to be at all satisfactorily established that the Duluth gabbro antedates the conglomerate. No pebbles of the gabbro have apparently been found in the conglomerate. The fact that the gabbro is inferior in position to the conglomerate is of no weight, since the gabbro is admittedly intrusive. The "red rock" pebbles are not necessarily derived from gabbro contacts. Mr. Winchell assumes that the Logan sills and dikes in the Animikie are offshoots from the gabbro intrusion, but this is shown to be improbable on petrographic grounds by Dr. Grant; and some of these sills and dikes have "red rock" contacts. The Duluth gabbro cannot be earlier than the Puckwunge conglomerate and at the same time the equivalent of the Logan sills; for the latter are intrusive in abundance not only in the Animikie but also in Keweenawan (Nipigon) strata overlying the conglomerate in the Thunder Bay district. It seems, moreover, that another inconsistency lies in the fact that the conglomerate is stratigraphically beneath the Beaver Bay diabase as mapped on the Cook County Plate, while the diabase is throughout the report regarded as the surface equivalent of the gabbro. Is it not entirely possible, for anything that Mr. Winchell knows to the contrary, that the Duluth gabbro was intrusive in late Keweenawan time and that some of the "red rock" of Cook County is due to the contact action of the gabbro against the Puckwunge sandstone? It is certainly remarkable, in view of Mr. Winchell's contention, that neither the geological mapping of Cook County nor the more

detailed Pigeon Point Plate shows any formations intervening between the Puckwunge conglomerate or sandstone and the Animikie; and the map is according to the writer's experience a correct expression of the relationship which prevails in the Thunder Bay district.

The relation of the Carltonian Anorthosites to the Duluth gabbro is not freely discussed in the report, but it seems to be assumed that they are the same formation. This again is inconsistent with the view that the Beaver Bay diabase is the surface equivalent of the gabbro, for the writer has shown that both at Beaver Bay and at Carlton Peak, the rocks now mapped as Beaver Bay diabase repose upon the worn surface of the anorthosite. It is futile to claim that the extensive areas of anorthosite seen under the lavas at Beaver Bay are inclusions in the lava, and the claim is reduced to an absurdity when the mountain mass of anorthosite at Carlton Peak is considered. The anorthosite is petrographically distinct from the gabbro; it shows none of the contact phenomena of the gabbro; it presents an uneven eroded surface upon which the Beaver Bay diabase, the oldest of the Keweenawan lavas, rests; the Beaver Bay diabase contains numerous included blocks of anorthosite which were evidently picked up by the lava as it flowed over the surface of the bare anorthosite, or which were detached from the walls of the vent from which the lava came to the surface; the resurrected surface of the anorthosite exposed by the removal of the lavas has the same hummocky uneven character as that which characterizes the pre-Animikie surface of the Archæan generally in the Lake Superior region; the anorthosite has a well-known equivalent in the Norian of Canada. These considerations render very questionable the correlation of the Carltonian anorthosite with the Duluth gabbro, and support the view that it is a distinct pre-Keweenawan formation.

The chapters on the counties in which the phenomena of the Pleistocene preponderate, written by Todd and Upham, and the incidental references to the same phenomena by Grant and Winchell, are important contributions to the subject, but here, again a coherent general discussion of these features, such as might be expected in a final report, would have greatly enhanced the value of the volume. The occasional summary statements by Todd and Grant are to be commended as efforts in this direction. The characters of the drift and its modifications, its special features such as kames and pitted plains, the distribution of moraines, these are all described in more or less detail; and the survey has placed students of the Pleistocene under obligations for its painstaking efforts to secure local information on these matters. The limits and shore features of Lake Agassiz are discussed especially by Todd and Grant, the shore features of Lake Warren by Grant, and the early outlet of Lake Superior as well as certain minor post-Glacial lakes by Upham. In most of the chapters there is a statement of the local features of economic interest; and the final chapter by H. V. Winchell on the iron industry is a valuable contribution to our knowledge of the great iron resources of the state.

ANDREW C. LAWSON.

2. *A Revision of the Genera and Species of Canadian Palæozoic Corals, the Madreporaria Perforata and the Alcyonaria;* by LAWRENCE M. LAMBE, pp. 1–96, plates i–v, 1899. (Contributions to Canadian Palæontology, Volume IV, Part I.)—This report is particularly interesting as adding to our knowledge of the Paleozoic corals some details as to their geological range and the characteristics marking their relation to time. The author notes that the genus Favosites, when occurring in the Cambro-Silurian or Silurian, has spiniform septa whilst those of the Devonian have squamulæ. This is a confirmation of Rominger's* observation. *F. Gothlandica* is observed to occur at numerous localities in the Niagara, Guelph and Lower Helderberg formations, in divisions 2, 3 and 4 of the Anticosti Group and in rocks of supposed Hudson River age. "The only difference between *F. Helderbergiæ* and *F. Niagarensis* appears to be in the shape of the corallum which in the former species 'is large, lenticular, depressed, convex or hemispherical,' and in the latter spherical or clavate, a difference which, though slight, may be considered sufficient, if it be constant, for the separation of the two species." In discussing the genus Calapœcia, the writer has been forced to regard *C. Canadensis*, *C. Huronensis* and *C. Anticostiensis* as belonging to the same species. *Syringopora bifurcata* Lonsdale, is reported from both the Niagara and Lower Helderberg formations. In the discussion of the genus Halysites, Mr. Lambe remarks that "Particular stress has been laid on the presence or absence of septal spines by Dr. Nicholson. In his 'Palaeozoic Tabulate corals,' p. 229, it is stated that 'the form known as *H. escharoides* Lam., is distinguished from the typical *H. catenularia* Linn., not only by the superficial characters just mentioned, but also by the constant possession of spiniform septa, and the apparently constant absence of small tubes between the large ones.' This is not borne out, however, by Canadian specimens. An example from the Niagara limestone of Ontario has tubules between the corallites admirably shown as well as rows of septal spines; other examples with tubules and septal spines have been collected at Lake Temiscaming (Niagara), at Cross Lake Rapids on the Saskatchewan River and at Cedar Lake (Niagara) and from the Lower Helderberg rocks of l'Anse-au-Gascon, l'Anse à la Barbe, etc., Baie des Chaleurs. When the tubules are present and the septal spines are not seen, it is possible that the latter, on account of their small size, have not been preserved or are not sufficiently distinct to be recognized. The gradation of one form of *H. catenularia* into another would lead to the belief that it consists of one typical form with several stratigraphical varieties; the typical form not being the oldest."

From a comparative study of the Canadian specimens, he concludes, "that *H. catenularia* and its varieties range from the Black River limestone at the base of the Trenton formation up to the rocks of the Lower Helderberg Group; and that the Black

* Geological Survey of Michigan, Fossil Corals, p. 19, 1876.

River limestone in eastern Canada, the Galena-Trenton of the Lake Winnipeg region, etc., in the west, the Hudson River, Niagara, Guelph and Lower Helderberg formations have their distinctive varieties."

Three varieties of *H. catenularia* from the Lower Helderberg are described and figured under the names of var. *simplex*, var. *amplitubulata*, and var. *nitida*. An analytical table of the species and varieties, and their characters in relation to range, is also given. The genus Heliolites also ranges from the Niagara into the Lower Helderberg. Plasmopora also appears in both formations. *Lyellia affinis* occurs in the Hudson River and Niagara formations, in the four divisions of the Anticosti group, and in the Lower Helderberg. W.

3. *Geological Survey of Canada.*—The Annual Report (new series, Vol. X, reports A, H, I, J, M, S, 1897) has recently been issued in book-form, 1899, comprising 1046 pages, accompanied by 8 maps and 12 plates; separate reports of which have already been noticed. The following maps accompany the volume:

560. Thunder Bay and Rainy River Districts, Ontario—Seine Sheet.

589. Thunder Bay District, Ontario—Lake Shebandowan Sheet.

599. Nipissing District, Ontario, and Pontiac Co., Quebec—Lake Temiscaming Sheet.

606. Nipissing District, Ontario, and Pontiac Co., Quebec—Lake Nipissing Sheet. W.

4. *The Geological Society of America: Cordilleran Section.*—The first annual meeting of a Cordilleran section of the Geological Society of America was held in San Francisco, Cal., Dec. 29 and 30, 1899. The section is composed of fellows of the Society too far distant from the places of ordinary meeting of the Society to attend its sessions. The following is a list of papers accepted for reading at the meeting:

F. W. Cragin: The discovery of a goat antelope in the cave fauna of Pike's Peak Region.

J. C. Merriam: On the occurrence of a ground sloth in the Quaternary of California: On the classification of the John Day beds.

James E. Talmage: Notes concerning erosion forms and exposures in the deserts of South Central Utah.

Horace B. Patton: Thomsonite and other zeolites from Golden, Colorado.

H. W. Fairbanks: The Peneplain question upon the Pacific Coast.

W. S. Tangier Smith: A topographic study of the Islands of Southern California.

Joseph Le Conte: An early geological excursion.

J. C. Branner: The sandstone reefs of Brazil.

E. W. Hilgard: The geological significance of soil study.

E. W. Claypole: The Devonian fishes of North America.

Andrew C. Lawson: The Berkeley Hills—A detail of Coast Range geology.

W.

5. *Key to the Upper Devonian of Southern New York*; by Gilbert D. Harris, Cornell University, Ithaca, N. Y. Co-operative Society. Price 28 and 35 cents, post paid.—The "Key to the

Upper Devonian" furnishes a means by which high schools and academies can give their students field work in Geology. After a brief introduction on the kinds and occurrence of rocks and definitions of a few important geological terms, a list of a large number of localities is given with the kind of rock, location of outcrop, and some of the important fossils of each. The pamphlet closes with 120 good figures of characteristic Upper Devonian fossils. This book of thirty-five pages is admirably qualified to make this subject, which is often considered difficult and uninteresting, really enjoyable, and will bring out the powers of observation of the student. Its convenient size, advice on field work, and especially the excellent illustrations of fossils make it a very valuable supplement to the elementary text-books for students in Geology, both in the secondary schools and in colleges. H. L. C.

6. *Principles and Conditions of the Movements of Ground Water;* by FRANKLIN H. KING. With a theoretical investigation of the Motion of Ground Waters, by CHARLES H. SLICHTER. Nineteenth Annual Report, U. S. Geological Survey, pp. 59–384.—The water which falls upon the land is evaporated from the place where it falls, or drains off through natural channels or sinks into the ground. The laws and effects of the first two movements are quite well understood, but little is known of the career of the considerable portion of water which enters the soil directly and which has such an important influence in geological processes and on the industries and domestic life of civilized and uncivilized peoples. The paper of Prof. King is an important contribution to this little known subject, and gives the results of well-planned experiments and careful observations. Chapter I deals with the amount of water stored in the ground and discusses in detail the character and extent of the gravitational, thermal, and capillary movements of the waters. Chapter II is devoted to the explanation and discussion of experimental investigations regarding the flow of fluids through various porous media. In Chapter III the author discusses the rate of flow of water though sands and rocks of different character and degrees of porosity, and calls attention to the influence of this factor on wells. With Prof. King's paper is one on the Theoretical Investigation of the Motion of Ground Water, by Prof. Slichter, in which are given the physical and mathematical data for the discussion of the whole subject. H. E. G.

7. *Geologic Atlas of the United States—Absaroka Folio, Wyoming.* (Crandall and Ishawood Quadrangles); Geology, by ARNOLD HAGUE, assisted by J. P. IDDINGS and T. A. JAGGAR, JR. Triangulation and Topography, by FRANK TWEEDY, Washington, 1899.—The area covered by these sheets is that east of and immediately adjoining that of the Yellowstone Park and thus continues in this direction into the Absaroka Range, the work published in the Yellowstone Park Folio. The six full pages of text (equal to about 70 pp. in ordinary 8°), give an admirably

summarized account of geology, while in addition to the topographic and geologic sheets there is one of columnar sections and one of illustrations.

The sedimentaries described range upward from the Archean, but they appear only in small amount on the map to the east and north, the greater part of the area being covered with volcanic ejections, breccias and flows cut in places by great numbers of dikes and pierced by intrusive masses. They range from rhyolites through andesites to basalts, the andesites of various types being especially prominent. These outbreaks took place over an already eroded country in Eocene and Neocene time. The erosion since then of these great masses of rather easily degraded material has resulted in most interesting and peculiar types of topography.

L. V. P.

8. *Preliminary Notice of the Etcheminian Fauna of Cape Breton;* by G. F. MATTHEW, LL.D., St. John, N. B., Canada. Nat. Hist. Soc. N. Bruns'k. Bull. XVIII, vol. iv, pp. 198.—This paper gives an account of the fossils found in Cape Breton, Nova Scotia, in a set of beds forming the lowest Paleozoic terrane in that province. The forms described are all either brachiopod or ostracod, and while the genera correspond to those of the Protolenus Fauna (Cambrian) in New Brunswick, the species are all different.

The forms described belong to the brachiopoda and ostracoda. Of the former new species are described belonging to the genera Lingulella, Leptobolus, Obolus, Acrothele and Acrotreta; the Obolus is said to belong to a new sub-genus (Protobolus) characterized by the approximation of the vascular trunks in the ventral valve.

The Ostracoda are all small and are referred to two genera, Bradoria (new) and Schmidtella.

The article is accompanied by four plates of figures and two sections to show the relation of the Etcheminian terrane to the formations above and below.

9. *Recent Foraminifera.* A Descriptive Catalogue of Specimens dredged by the U. S. Fish Commission steamer Albatross; by JAMES M. FLINT, M.D., U. S. N., Honorary Curator, Division of Medicine, U. S. National Museum. (From the Report of the U. S. National Museum for 1897, pp. 248–349, with eighty plates. Washington, 1899.)—The purpose of this catalogue, as stated in the preface, is to record the additions to our knowledge of the Foraminifera obtained by the deep-sea dredgings of the Albatross. In order to show its place in the literature of the subject it may be well to compare it with Brady's classic report on the Foraminifera collected by the Challenger expedition.

The latter consists of 814 pages and 145 plates, comprising an introduction discussing the chief problems presented by this group of Protozoa, followed by a bibliography, a new classification, and the detailed descriptions of genera and species. At the close of the Challenger report are tables showing the distribution

of certain species, in area, in depth, and over diverse bottoms. Finally, there are maps giving the location of the two hundred and eight stations which furnished material for the examination.

The majority of Foraminifera are of such world-wide distribution that, although the soundings are few compared to the vast area of the oceanic basins, large portions of which are still entirely unexplored, new expeditions will not greatly increase the number of species, but will rather give more precisely their areal limits and dependence upon environment. It is in these respects that the Albatross report has its chief value, yet it embraces many features which make it the most important contribution to the subject since the Challenger report of 1884. The latter included the results of one hundred and forty stations observed by the Challenger naturalists, twenty-four of these being in the north Atlantic, with sixty-eight recorded by other expeditions from points surrounding the British isles, and in the Arctic ocean. The present report, on the contrary, includes observations from ninety-two stations, of which fifty-eight are from the north Atlantic, twenty-one from the Gulf of Mexico, and seven from the Caribbean sea. Into the last two areas the Challenger expedition did not go.

The title of Flint's memoir hardly indicates its value, as the report is really a volume supplemental to that by Brady. It consists of a short preface and introduction, and an analytical key to the families and genera of the Foraminifera, which to the student having only a slight knowledge of this subject should be of considerable assistance. Detailed descriptions of the families, genera, and species are then given and these are followed by the plates. The last are worthy of especial mention, being reproductions from photographs of two hundred and ninety-nine species belonging to seventy-two genera, the original specimens of which are on exhibition in the National Museum.

These photographs are to a uniform enlargement of fifteen diameters, a plan which should aid in the ready determination of species, since the size as well as the form is evident at a glance. Besides being clear and sharp, the reproductions are characterized by a striking relief and truthfulness. Brady's classification is adopted bodily and the species are arranged on the plates so as to best bring out their relationships.

Among the Foraminifera the transition of forms is so nearly complete that any classification into orders is bound to separate genera which are closely related. This, however, is a difficulty to be anticipated in every branch of natural history as the extinct progenitors become better known. In such cases the best ultimate solution may be to establish several basal or primitive orders, with the understanding that their boundaries are not the well-defined limits shown by the separated groups of later and better differentiated descendants. But it is not likely that a classification of the Foraminifera better than Brady's will soon be made.

The present catalogue no doubt could have been made more

valuable and complete had the author collected the scattered and missing facts regarding the environments, into tables similar to those given at the end of the Challenger report, thus showing the abundance and distribution of the species, their relation to the character of bottom, temperature of water, and vicinity to land. A map would also have been useful as indicating at a glance the location of the stations. However, the author is to be congratulated on having produced a hand-book complete in itself, yet supplementary to the work already published. It deals with nearly half the number of stations and the results are given on more than half as many plates as the Challenger report which it supplements.

For the working student it will serve as the best hand-book on the Foraminifera, yet its value is liable to be overlooked by the casual reader. J. B.

10. *Guida al Corso de Mineralogia* di Antonio D'Achiardi, Professore nell' Univesità di Pisa. Mineralogia generale, 8vo, pp. 1–339. Pisa, 1900 (Enrico Spœrri).—The author of this work is well known for his many contributions to Italian mineralogy, and for his two excellent works, one on metallic minerals and their deposits and the other on lithology. He has here given an excellent presentation of the general subject of mineralogy, including first, the morphology of crystals with a discussion of the systems of crystallization presented according to modern methods; also the physical characters, and the chemical characters of minerals. The physical characters are presented with especial completeness and system.

Obituary.

Thomas Egleston, for many years Professor of Mineralogy and Metallurgy in the School of Mines of Columbia University, New York City, died on January 15th, at the age of sixty-seven years. Professor Egleston was born in New York City, December 9th, 1832, and was graduated at Yale College in 1854; later studies were carried on abroad, especially at the École des Mines in Paris. In 1864, largely through his efforts, the Columbia School of Mines was founded under at first very discouraging conditions. This work, which has later been followed by the development of a flourishing and highly useful institution of learning, may well be considered the most important achievement of his life. For more than thirty years, until his retirement in July 1, 1897, he held the Chair of Mineralogy and Metallurgy and was always active in promoting the progress of the School. He was also largely interested in the founding of the American Institute of Mining Engineers and its Transactions contain a number of papers by him; he also published articles in other periodicals: among larger publications may be mentioned his Catalogue of Minerals and Synonyms alphabetically arranged (Washington, 1889 and New York, 1891).

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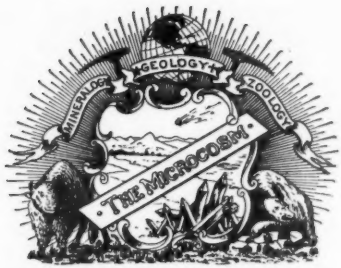

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(1) Described in this Journal Sept., 1895. (2) Ibid Nov., 1887. (3) Proc. Roch. Acad. Sci. Vol. 1. (4) This Journal Aug., 1888. (5) Ibid July, 1893. (6) Ibid June, 1894. (7) Ibid Nov., 1892.

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